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A

DICTIONARY

OF

ARTS, MANUFACTURES

AND

MINES;

CONTAINING

A CLEAR EXPOSITION OF THEIR PRINCIPLES AND PRACTICE

BY

ANDREW URE, M. D.,

F.R.S. M.G.S. M.A.S. LOND.; M. ACAD. N.S. PHILAD.; S. PH. SOC. N. GERM. HANOV.; MULII. ETC. ETC.

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PREFACE.

It is the business of operative industry to produce, transform, and distribute all such material objects as are suited to satisfy the wants of mankind. The primary production of these objects is assigned to the husbandman, the fisherman, and the miner; their transformation to the manufacturer and artisan; and their distribution to the engineer, shipwright, and sailor.* The unworked or raw materials are derived,—1. from the organic processes of vegetables and animals, conducted either without or with the fostering care of man; 2. from the boundless stores of mineral and metallic wealth, arranged upon or within the surface of the earth by the benignant Parent of our being, in the fittest condition to exercise our physical and intellectual powers in turning them to the uses of life.

The task which I have undertaken in the present work, is to describe and explain the transformations of these primary materials, by mechanical and chemical agencies, into general objects of exchangeable value, leaving, on the one hand, to the mechanical engineer, that of investigating the motive powers of transformation and transport; and, on the other hand, to the handicraftsman, that of tracing their modifications into objects of special or local demand. Contemplated in this view, an art or manufacture may be defined to be that species of industry which effects a certain change in a substance, to suit it for the general market, by combining its parts in a new order and form, through mechanical or chemical means. Iron will serve the purpose of illustrating the nature of the distinctions here laid down, between mechanical engineering; arts and manufactures; and handicraft trades. The engineer perforates the ground with a shaft, or a drift, to the level of the ore, erects the pumps for drainage, the ventilating, and hoisting apparatus, along with the requisite steam or water power; he constructs the roads, the bridges, canals, railways, harbors, docks, cranes, &c., subservient to the transport of the ore and metal; he mounts the steam or water-power, and bellows for working the blast-furnaces, the forges, and the cupolas; his principal end and aim on all occasions being to overcome the forces of inertia, gravity, and cohesion The ores extracted and sorted

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* For correct and copious information upon *agricultural* production, I have great pleasure in referring my readers to Mr. Loudon's elaborate *Encyclopedias of Agriculture, Gardening, and Plants;* and for *mercantile* production and distribution, to Mr. M'Culloch's excellent *Dictionary of Commerce and Commercial Navigation.*

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by the miner, and transported by the engineer to the smelting station, are there skilfully blended by the iron-master (manufacturer), who treats them in a furnace appropriately constructed, along with their due proportions of flux and fuel, whereby he reduces them to cast iron of certain quality, which he runs off at the right periods into rough pigs or regular moulds; he then transforms this crude metal, by mechanical and chemical agencies, into bar and plate iron of various sizes and shapes, fit for the general market; he finally converts the best of the bars into steel, by the cementation furnace, the forge, and the tilt-hammer, or the best of the plates into tin-plate. When farther worked by definite and nearly uniform processes into objects of very general demand in all civilized countries, these iron and steel bars still belong to the domain of manufactures; as, for example, when made into anchors, chain-cables, files, nails, needles, wire, &c.; but when the iron is fashioned, into ever varying and capricious forms, they belong either to the general business of the founder and cutler; or to the particular calling of some handicraft, as the locksmith, gratesmith, coachsmith, gunsmith, tinman, &c.

Such are the principles which have served to guide me in selecting articles for the present volume. By them, as a clew, I have endeavored to hold a steady course through the vast and otherwise perplexing labyrinth of arts, manufactures, and mines; avoiding alike engineering and mechanical arts, which cause no change in the texture or constitution of matter,—and handicraft operations, which are multiform, capricious, and hardly susceptible of scientific investigation. In fact, had such topics been introduced into the volume, it would have presented a miscellaneous farrago of incongruous articles, too numerous to allow of their being expounded in a manner either interesting or instructive to the manufacturer and the metallurgist. I readily acknowledge, however, that I have not been able to adhere always so rigorously as I could have wished to the above rule of selection; having been constrained by intelligent and influential friends to introduce a few articles which I would gladly have left to the mechanical engineer. Of these *Printing* is one, which, having had no provision made for it in my original plan, was too hastily compiled to admit of my describing, with suitable figures, the flat-printing automatic machine of Mr. Spottiswoode, wherewith the pages of this volume were worked off; a mechanism which I regard as the most elegant, precise, and productive, hitherto employed to execute the best style of letter press.

I have imbodied in this work the results of my long experience as a Professor of Practical Science. Since the year 1805, when I entered at an early age upon the arduous task of conducting the schools of chemistry and manufactures in the Andersonian Institution, up to the present day, I have been assiduously engaged in the study and improvement of most of the chemical and many of the mechanical arts. Consulted professionally by proprietors of factories, workshops, and mines of various descriptions, both in this country and abroad, concerning derangements in their operations, or defects in their products, I have enjoyed peculiar opportunities of becoming familiar with their minutest details, and have frequently had the good fortune to rectify what was amiss, or to supply what was wanting. Of the stores of information thus acquired, I have availed myself on the present occasion; careful, meanwhile, to neglect no means of knowledge which my extensive intercourse with foreign nations affords.

I therefore humbly hope that this work will prove a valuable contribution to the literature of science, serving—

In the first place, to instruct the Manufacturer, Metallurgist, and Tradesman, in the principles of their respective processes, so as to render them in

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reality the masters of their business, and to emancipate them from a state of bondage to such as are too commonly the slaves of blind prejudice and vicious routine.

Secondly, to afford to Merchants, Brokers, Drysalters, Druggists, and Officers of the Revenue, characteristic descriptions of the commodities which pass through their hands.

Thirdly, by exhibiting some of the finest developments of chemistry and physics, to lay open an excellent practical school to students of these kindred sciences.

Fourthly, to teach Capitalists, who may be desirous of placing their funds in some productive bank of industry, to select judiciously among plausible claimants.

Fifthly, to enable Gentlemen of the Law to become well acquainted with the nature of those patent schemes which are so apt to give rise to litigation.

Sixthly, to present to our Legislators such a clear exposition of our staple manufactures, as may dissuade them from enacting laws which obstruct industry, or cherish one branch of it to the injury of many others: and,

Lastly, to give the General Reader, intent chiefly on *intellectual cultivation*, a view of many of the noblest achievements of science, in effecting those grand transformations of matter to which Great Britain owes her paramount wealth, rank, and power among the kingdoms.

The latest statistics of every important object of manufacture is given from the best, and, usually, from official authority, at the end of each article.*

The following summary of our manufactures is extracted from Mr. Macqueen's *General Statistics of the British Empire*, published in 1836. It shows the amount of capital embarked in the various departments of manufacturing industry, and of the returns of that capital:—

	Capital.	Produce.
	£	£
Cotton manufactures - - - -	40,973,872	52,513,586
Woollen ditto - - - - - -	36,000,000	44,250,000
Silk ditto - - - - - -	8,000,000	10,000,000
Linen ditto - - - - - -	12,000,000	15,421,186
Leather ditto - - - - - -	13,000,000	16,000,000
Iron ditto, to making pig iron - - -	10,000,000	7,098,000
Iron, hardware, cutlery, &c. - - - - -	25,000,000	31,072,600
Copper and brass ditto - - - - - -	3,600,000	4,673,186
China, glass, &c. - - - - - - - -	8,600,000	10,892,794
Paper, furniture, books, &c. - - - - -	10,000,000	14,000,000
Spirits (British), ales, soap, &c. - - - -	37,600,000	47,163,847
Sundries additional - - - - - - - -	- -	9,000,000
Totals - - - - - - -	201,773,872	262,085,199

Although I am conscious of having used much diligence for many years in collecting information for this work, from every quarter within my reach, the utmost pains in preparing it for publication, and incessant vigilance during its passage through the press, yet I am fully aware that it must contain several errors and defects. These I have studied to rectify in the text of this fourth edition.

Since this book is not a Methodical Treatise, but a Dictionary, one extensive subject may be necessarily dispersed through many articles. Thus, for

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* The statistics of agriculture, trade, and manufactures, are ably and fairly discussed in Mr. McCulloch's *Dictionary* already referred to.

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example, information upon the manufacture of *Colors* will be found under azure; black pigment; bone-black; bronze; brown dye; calico-printing; carmine; carthamus; chromium; cochineal; crayons; dyeing; enamels; gold; gilding; gamboge; gray dye; green dye; green paints; indigo; kermes; lac dye; lakes; madder; massicot; mercury, periodide of; Naples yellow; orange dye; orpiment; paints, grinding of; ochres; paper-hangings; pastes; pearl white; Persian berries; pottery pigments; Prussian blue; purple of Cassius; red lead; rouge; Scheele's green; Schweinfurth green; stained glass; terra di Sienna; ultramarine; umber; verditer; vermilion; vitrifiable colors, weld, white lead; woad, yellow king's.

A casual consulter of the Dictionary, who did not advert to this distribution, might surmise it to be most deficient, where it is in reality most copious.

The elaborate and costly Encyclopedias and Dictionaries of Arts, which have appeared from time to time in this country and abroad, have, for the most part, treated of the mechanical manufactures more fully and correctly than of the chemical. The operations of the former are, in fact, tolerably obvious and accessible to the inspection of the curious; nor are they difficult to transfer into a book, with the aid of a draughtsman, even by a person but moderately versed in their principles. But those of the latter are not unfrequently involved in complicated manipulations, and depend, for their success, upon a delicate play of affinities, not to be understood without an operative familiarity with the processes themselves. Having enjoyed the best opportunities of studying the chemical arts upon the greatest scale, in this kingdom and on the Continent, I may venture, without the imputation of arrogance, to claim for my work, in this respect, more precision and copiousness than its predecessors possess. I have gone as far in describing several curious processes hitherto veiled in mystery, as I felt warranted, without breach of confidence, to go; regarding it as a sacred duty never to publish any secret whatever, without the consent of its proprietor. During my numerous tours through the factory districts of Great Britain, France, Belgium, Germany, and Switzerland, many suggestions, however, have been presented to my mind, which I am quite at liberty to communicate in private, or carry into execution, in other districts too remote to excite injurious competition against the original inventors. I am also possessed of many plans of constructing manufactories, of which the limits of these volumes did not permit me to avail myself, but which I am ready to furnish, upon moderate terms, to proper applicants. May I venture to point attention to the very insecure tenure by which patents for chemical or chemico-mechanical inventions are held; of which there is hardly one on record which may not be readily invaded by a person skilled in the resources of practical chemistry, or which could stand the ordeal of a court of law, directed by an experienced chemist. The specifications of such patents stand in need of a thorough reform; being for the most part not only discreditable and delusive to the patentees, but calculated to involve them in one of the greatest of evils—a chancery suit.

While I gratefully acknowledge the indulgence with which this work has been received, may I be permitted to advert very briefly to some of my present endeavours to render it less undeserving of public favor, though, after all my efforts, it will by no means realise either my own wishes and intentions, or the expectations of all my readers?

To investigate thoroughly any single branch of art, we should examine it in its origin, objects, connexion with kindred arts, its progressive advancement, latest improved state, and theoretical perfection. The general principles on which it is founded, whether belonging to the mechanical, the physical,

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the chemical sciences, or to natural history, should be fully expounded, and tested by an application to its practical working on the great scale. The maximum effect of the machinery which it employs, and the maximum product of the chemical mixtures and operations which it involves, should in every case be calculated and compared with the actual results.

Such have been my motives in the numerous consultations I have had with manufacturers relatively to the establishment or amelioration of their factories; and when they are kept steadily in view, they seldom fail to disclose whatever is erroneous or defective, and thereby lead to improvement. It will not be denied by any one conversant with the productive arts, that very few of them have been either cultivated or described in this spirit. It is to be hoped, however, that the period is not remote, under the intellectual excitement and emulation now so prevalent in a peaceful world, when manufactories will be erected, and conducted upon the most rational and economical principles, for the common benefit of mankind. Meanwhile it is the duty of every professor of practical science to contribute his mite towards this desirable consummation.

It is under a sense of this responsibility that I have written the leading articles of this edition, having enjoyed some peculiar advantages in my profession for making the requisite researches and comparisons. I trust that not many of them deserve to be regarded as trite compilations or as frivolous novelties, with the exception of a few of the notices of recent patents, which I have intentionally exhibited as beacons to deter from the treacherous quicksands, not as lights to friendly havens. I have sought sincerely to make them all conducive, more or less, to utility; being either new contributions to the old stock of knowledge, or additions and corrections to the present double volume.

Manufacture is a word which, in the vicissitude of language, has come to signify the reverse of its literal intrinsic meaning; for it now denotes every extensive product of art which is made by machinery, with little or no aid of the human hand; so that the most perfect manufacture is that which dispenses entirely with *manual* labor.

In every well-governed state of continental Europe there exists a Board of Health, or *Conseil de Salubrité* composed of eminent physicians, chemists, and engineers, appointed to watch over whatever may affect injuriously the public health and comfort. In France, this commission consists, for the capital, of seven members, who have the surveillance, in this respect, of markets, factories, places of public amusement, bakeries, shambles, secret medicines, &c. This tribunal has discharged its functions to the entire satisfaction of their fellow citizens, as appears from the following authentic report:—"*Non seulement une foule de causes d'insalubrité disparurent, mais beaucoup de moyens, de procédés nouveaux furent proposés pour assainir les Arts et les Métiers, qui jusque là avaient part inséparables de ces causes d'insalubrité ; la plupart de ces moyens eurent un plein succès. Il n'y a pas d'exemple que les membres du Conseil appellés, à donner leur avis sur les plaintes formées contre des fabriques, aient jamais répondu qu'il fallait les supprimer sans avoir cherché eux-mêmes à aplanir les difficultiés, que présentait aux fabricants, l'assainissement de leur art, et presque toujours ils sont parvenu à resoudre le problème. Le Conseil de Salubrité, que l'on ne saurait trop signaler à la reconnaissance du publique, est une institution que les nations étrangères admirent, et s'efforceront d'imiter sans doute.*"

From this confident hope of emulation by other nations, the author of these excellent observations would have excepted the United Kingdom, had he known how little paternal care is felt by the government for the general interests of the people. In Germany, indeed, where the *fatherland* feeling is strong in the breasts even of those rulers whom we are apt to consider despots, similar boards of health are universally established, whereas our legislative oligarchy frames laws chiefly for the benefit of its own class and dependents; as happened in the old time, when there was no king in Israel to regard alike the interests of the poor and the rich.

The Prussian municipal law (*Allgemeine Landrecht*) contains the following enactments with regard to the sale of spoiled or adulterated victuals. Th. II. Tit. 20.; Abschnitt 11, §§ 722 to 725. "No person shall knowingly sell or communicate to other persons for their use, articles of food or drink which possess properties prejudicial to health under a penalty of fine or bodily punishment. Whosoever adulterates any such victuals in any manner prejudicial to health, or mixes them with unwholesome materials, especially by adding any preparation of lead to liquors, shall, according to the circumstances of the case, and the degree of danger to health, be liable to imprisonment in a correction house, or in a fortress, during a period varying from one to three years. Besides this punishment, those who are found guilty of knowingly selling victuals which are damaged or spoiled (*verdorbener*), or mixed with deleterious additions, shall be rendered incapable for ever of carrying on the same branch of business. The articles in question shall be destroyed if incorrigibly bad, but if otherwise, they are to be improved as far as possible at the cost of the culprit, and then confiscated for the benefit of the poor. Further, whosoever mixes victuals or other goods with foreign materials, for the purpose of increasing their weight or bulk, or their seeming good qualities, in a deceitful manner, shall be punished as a swindler."

It is singular how, amid the law-making mania which has actuated our senators for many sessions, that not even one bill has been framed for the protection of the people from spoiled and adulterated foods and drinks."*

Many novelties of an interesting and useful nature, first displayed in the late Grand Exhibition of the Industry of all Nations, which had not been noticed in the alphabetical places as patent or other inventions, are here described with merited commendation; though at the hazard, sometimes, of a little repetition. This valuable portion of the Dictionary was accomplished with the aid of the able abstracts made by the ingenious authors of a series of articles inserted in successive numbers of "Newton's London Journal of Science."

The candid critic will take into view the number of original disertations now introduced, and treated at considerable length. On comparing these with the usual staple with which similar books are made up, he will recognize my diligence at least, and make allowance for a few oversights. He will see, that having fully availed myself of the facilities offered by the alphabetical distribution of the subjects, I have been able to amend, under an equivalent title, what seemed amiss under the main head. Thus, for example, the elegant new art, for which we are indebted to Daguerre, may be considered in connection with his name, as also under the title Photography, or better perhaps under that of Heliography, or Sun-painting; since the solar rays are the preferable excitant. As it has been also termed Calotype, under this name Sun-painting has been briefly noticed.

In the mechanical department of the Dictionary, I have received valuable contributions from the two distinguished engineers, Mr. William and Mr. Peter Fairbairn, brothers. The first is generally recognized all over the factory world as eminent for the originality, grandeur, and justness of his inventions. It has been my good fortune to be conversant with his magnificent workshops, in Manchester and Millwall, during very many years, and I have

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* See the article "PROVISIONS, PRESERVED."

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always regarded them as the best mechanical schools in the kingdom. Mr Fairbairn commenced his brilliant career as a factory millwright, by discarding the heavy and clumsy square shafts and drums of Arkwright and his compeers, and replacing them by slender rods of wrought-iron, and cast-iron pulleys; causing these to revolve with such a velocity as fully compensated for their diminished weight, according to the true principles of dynamics. He thus effected an immense and most beneficial revolution in factory-construction, in cotton, corn, flax and silk mills; enabling the machinery to be driven with far less power and greater precision.

His next important step was a general improvement in mill architecture; the construction of fire-proof buildings; as also mounting the fly-wheels of steam-engines, with teeth on their periphery, into first motions. This change was condemned by some millwrights at the time, but has since become general. The investigation of the strength of cast-iron beams, and a greatly improved style of building, by the introduction of pilasters at the corners, completed his system of fire-proof spinning works. This plan has been since copied in all the textile factories.

The experiments referred to, and the construction of several iron steamboats, led him to the extensive use of iron as as a material for shipbuilding. Though Mr. Fairbairn was not the first to build iron boats, yet he and his then partner, Mr. Lillie, were the first to show how this material should be best applied.

The system of working steam-engines expansively, by means of revolving discs, which is also very extensively used, with the saving of one half of the fuel, was contrived by Mr. Fairbairn about this time.

We have now arrived at the grand consummation of his mechanical genius—the tubular bridges and tubular cranes.

His bridges across the Conway river and the sea straits of Menai are such stupendous and marvellous creations of engineering enterprize, as to have cast all former mechanical exploits into the shade, and to have led to the notion that nothing of a like description was ever undertaken or executed by him. Hence, perhaps, I may be blamed for using the expression Fairbairn's Tubular Bridges. Fifty-two tubular bridges have been already erected in this and other countries by this unparalleled *Pontifex Maximus.*

In fact, Mr. Fairbairn's title to the honor of inventing the genuine rectangular tubular bridge, not the spurious cylindrical or elliptic form, is as clear as that of Sir Isaac Newton to the invention of the binomial theorem, or Sir H. Davy to that of the miners' safety lamp.

I am indebted, with my readers, to Peter Fairbairn, Esq., of Leeds, undoubtedly the great and the best manufacturer of flax machinery and flax mills, for the article FLAX. He has been ably assisted by the engineers of his princely establishment, and especially by Mr. Robert Busk.

Many most ingenious and instructive disquisitions are due to my worthy chemical friend, Mr. Lewis Thompson, and that particularly under the head COAL, in the body of the work; and in the following few remarks. That there is nothing personal in the language is clear from this, that it is an exact transcript of the original Government Report.

Few persons at all alive to the enormous importance of the question at issue will consider it possible to be too critical in a matter so notoriously associated with our national power, welfare, and prosperity. After all, however, the remarks must speak for themselves. Nevertheless, lest their merits should be called in question, it becomes necessary to demonstrate, not only that they are correct and just, but that even the gentlemen engaged in this coal investigation themselves bear evidence to the scientific accuracy of those

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very remarks, and have actually modified their subsequent reports in accordance with the principles there first developed. But over and beyond all this, it will now be shown, from practical results obtained during many years by the most impartial experimentalists, that the views there displayed respecting the calorific power of fuel are strictly in accordance with facts of the most obvious and certain nature, and should lead to a vast economy in steam navigation.

Without needlessly dilating therefore upon the value of the evidence now about to be given, I shall at once proceed to offer the evidence itself, and leave the public to draw an unbiassed conclusion.

In the first Admiralty Report it was attempted to be proved "that the evaporative value of a bituminous coal is expressed by the evaporative value of its coke, the heat of combustion of its volatile products proving in practice little more than that necessary to volatilize them." And this foregone conclusion was found to be verified by column B. of Table VI., which proved "that, notwithstanding several striking exceptions which might have been expected, the experiments *on the whole* show the work capable of being performed by the coke alone is actually GREATER than that obtained by experiments with the original coal."

Again, as regards the nitrogen contained in coal, it was asserted, that the whole system of manufacturing coke is at present very defective; that "an immense quantity of ammonia is lost by been thrown into the atmosphere;" and that "by a construction of the most simple kind, the coke ovens now in use might be made to economize much of the nitrogen which invariably escapes in the form of ammonia." And accordingly a column of Table VI. was set apart for the purpose of rousing the dormant energies of coke makers by showing "the amount of sulphate of ammonia" which, "by a construction of the most simple kind," they could get from the coals.

Again, it was laid down, that it is *easy* from analysis to examine whether the duty performed by the coal is to be attributed to its fixed ingredients (ingredient?) or coke;" and hence a column in Table VI. was given to show the theoretical "number of lbs. of water convertible into steam by the coke left by the coal."

Again, in the First Report, "the area of the damper open" was for the most part kept uniform in different trials with the same coal; as, for example, with the Penterfelin, the Duffryn, Wards Fiery vein, the Binea, the Llangenneck, the Mynydd Newydd, the Graigola, &c. &c. &c., a change in the area being the exception. Now in all these respects the Reports No. 2. and 3. differ entirely from Report No. 1., as also in respect to certain proximate analyses which were contained in No. 1. Report.

The "theoretical lbs. of water convertible into steam by the coke" have disappeared; the ammonia and sulphate of ammonia to be got by "a construction of the most simple kind" have disappeared; the proximate analyses have disappeared; the foregone conclusion respecting the coke of bituminous coal has not only disappeared, but met with a direct negative answer upon practical trial; "the area of the damper open" has been never twice alike with the same coal, nay the very litharge experiments have been arranged so as to compensate for the errors arising from iron pyrites; and lastly, we find that it is not only *not* "*easy* from the analysis to examine," &c., but even the calorific coke theory is abandoned in Report No. 3., for it there appears that the analyses show generally that, although the "quantities of carbon and *hydrogen* regulate materially the economic values of the coals," yet in spite of these analyses "the inquiry would have been far from sufficient, had we not elicited the economic values of the coals by actual trial under the boilers,"—a result

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not varying much from our former dictum, that "a good stoker was of more importance than a scientific chemist for such an investigation." And how in fact can it be otherwise, when we find that the analyses were made on such a scale that "more accurate results were obtained by operating upon *three or four grains* than upon a larger quantity!!"

The great principle contended for in our previous remarks was that the volatile constituents of a bituminous coal, so far from being worthless in a calorific point of view, were on the contrary of the greatest importance. Now this, though in direct opposition to the deductions of Report No. 1, can be proved to demonstration from the results of Report No. 2.; and hence no doubt the reason why we find in Report No. 3 that the quantities of carbon and *hydrogen* regulate materially, &c. At page 45 of Report No. 2, a comparative experiment is recorded for the purpose of determining whether the coke of a bituminous coal or the coal itself possessed the greatest evaporative power; for as we have seen in Report No. 1, the "work capable of being performed by the coke alone was actually *greater* than that obtained with the original coal." The coal employed in this experiment was the Tanfield, and it yielded 65 per cent. of coke; the coke was made from the same coal by Messrs. Cory & Son, of New Barge House, Lambeth, names too well known for the excellence of their manufacture to require comment here. The experiments were carried on for 34 consecutive hours with each material, and the total amount of water evaporated was 33,170 lbs. or about 15 tons. So far, however, from finding that "the evaporative value of a coal is expressed by the evaporative value of its coke," which in this case was 65 per cent. only, lo! the experiments prove that the evaporative power of the coal was 20·1 per cent. greater, weight for weight, than that of the coke, or about 50 per cent.! greater than its own amount of coke!!—thus showing that the 35 per cent. of volatile ingredients were absolutely equal in heating power to the whole of the coke!!! And strange to say, this is borne out exactly by the results obtained in the manufacture of gas, in which, as is quite notorious, each gallon of tar, weighing from 10½ to 11 lbs. is found to have a calorific power equal to half a bushel of coke weighing from 21 to 23 lbs. There is not a gas engineer in Great Britain ignorant of this important fact, nor the secretary of a gas works, who, with coke at 4*d.* per bushel, estimates coal tar as fuel at less than 2½*d.* per gallon; and we happen to have now before us a series of actual workings extending over very long periods of time since the year 1831, and made by the engineer of the largest gas works in the world, for the express purpose of ascertaining the practical details connected with the relative economy of coal tar, coal and coke, and from which we have deduced the following, as the average values of these combustibles expressed in pounds of coal carbonized or distilled by the same weight of each:—

Tar equal	5 lbs
Newcastle coal equal	4½ lbs.
Coke from do. equal	3¾ lbs.

the "breeze" employed with the tar being deducted and estimated as equal to ¾ths of its weight of coke.

In point of fact, however, the relative value of coal and coke may be more decidedly determined by examining the heating power of the whole of the products of a ton of coal, and deducting therefrom the fuel employed in the distillation. For example, a ton of Newcastle coal may be distilled practically by 11 bushels of its own coke, and it will then yield about 36 bushels of coke, 4 bushels of breeze, 10 gallons of tar, and 9500 cubic feet of gas of specific gravity ·400. Consequently the heating power of the tar and gas taken together ought, upon the hypothesis assumed in the Admiralty Report No. 1, to be equal only to that of 11 bushels of coke, "the heat of the volatile products, &c., being only sufficient to volatilize them." Now it has been demonstrated over and over again, that every cubic foot of the aforesaid gas will practically boil off 2950 grs. of water, therefore 9500 cubic feet will boil off 4000 lbs. of water.

But since the 11 bushels of coke employed in carbonizing the coal weigh only about 460 lbs., and the evaporative value even of the best oven coke, according to the Admiralty Coals Report, is only 7·91 for every lb. (vide page 46, Report No. 2), it follows that the 11 bushels in question would only evaporate 3538 lbs. of water, or less by 462 lbs. than the gas alone, without taking into account the evaporative power of the 10 gallons of tar, and which cannot be assumed at less than **2000** lbs. upon the lowest computation. Consequently our facts, and the hypothesis contained in the First Admiralty Report stand as under:

Hypothesis.	Practical Facts.
One ton of coals carbonized by the heat of its volatile constituents affords 40 bushels or 1680 lbs. of coke, equal to the evaporation of 13,378 lbs. of water.	One ton of coal carbonized by 11 bushels of coke affords 9500 cubic feet of gas, 10 gallons of tar, and 40 bushels of coke, from which latter 11 are to be deducted. Thus leaving as the total heating power:

	lbs. of water.
29 bushels, or 1218 lbs. of coke equal to - - -	9634
9500 cubic feet of gas equal to -	4000
10 gallons of tar equal at least to	2000
Total lbs.	15,634

or nearly 20 per cent. more than the coke, a result which not only agrees with the practical experiments made with the Admiralty boiler, but also with the statements of Mr. Clegg, who indeed makes the difference greater, that is, 21 per cent. in favor of coal. Mr. Clegg, in the second edition of his practical treatise on Coal Gas, just published, gives the following as the relative amounts of coal, coke, or coal tar required to distil one chaldron of coals:

Coal Tar from 24 to 27 gallons, or from 264 to 297 lbs.
Coal from 5 to 5½ cwt., or from 560 to 616 lbs.
Coke from 16 to 18 bushels, or from 672 to 756 lbs.

He also estimates coal tar at 3*d.* per gallon.

If arguments of this kind do not conclusively establish the validity of our first remarks, we can scarcely hope to demonstrate any truth whatever; for these conclusions are drawn from actual data, the result of many years of labor undertaken by several different individuals, in different localities, having discordant interests in all respects but one, and that one the discovery of the simple truth with a view to practical economy in fuel, in establishments where the fuel accounts annually reach many thousands of pounds sterling.

If it be demanded how it happens that these results differ so materially from the great bulk of those arrived at by the Admiralty boiler, we might very properly refer the question to the fabricators of the three Admiralty Reports; but the causes of that difference are too obvious to escape the most superficial observer; and therefore, without wearying the reader by a tedious recapitulation, we will merely collate a few instances from these Reports, which prove, beyond the possibility of contradiction that the boiler experi-

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ments were totally inconclusive even upon the assumptions of the experimenters themselves.

We have before called attention to the want of varied adjustment in the open area of the damper in most of the experiments in Report No. 1; this objection is seen very forcibly in Reports Nos. 2 and 3, where it not unfrequently happens that between 112 inches of area and 56 inches, the value of the same coal is found to vary as much as 20 per cent. Such being the case, it is but reasonable to conclude that where a coal has gone on during three experiments increasing in value as the open area of the damper was increased, that the value of that coal has not been developed simply because the proper extent of the open area has not been reached in any of the experiments. As examples where the area has been too small, we may cite the following:—

	Area.	Area.	Area.
Blackbrook Rushy Park coals	112	56	84
Result	8·62 lbs.	7·55 lbs.	7·89 lbs.
	Area.	Area.	Area.
Blackbrook Little Delf	112	56	84
Result	8·57 lbs.	8·13 lbs.	8·17 lbs.
	Area.	Area.	Area.
Johnson and Wirthington's Rushy Park	112	56	85
Result	8·59 lbs.	7·83 lbs.	7·62 lbs.
	Area.	Area.	Area.
Lynvi coal	112	56	84
Result	9·61 lbs.	8·89 lbs	9·08 lbs.
	Area.	Area.	Area.
Balcarras five feet nine	112	56	84
Result	7·79 lbs.	6·60 lbs.	7·23 lbs.
	Area.	Area.	Area.
Hastings Hartley	112	56	84
Result	8·18 lbs.	7·65 lbs.	7·49 lbs.

And in precisely the same condition are the Balcarras Arley, Carr's Hartley, Hedley's Hartley, Bate's West Hartley, Davison's West Hartley, Cowpen and Sidney Hartley, Hill's Plymouth Coals, the Willington Coal, the Wigan Four Foot Seam, and a host of others, in Report No. 3, all of which would no doubt have given a better result with an increased opening in the damper. Conversely, we find many others with too large an opening, as for example:

	Area.	Area.	Area.
North Percy Hartley	112	56	84
Result	7·43 lbs.	7·74 lbs.	7 54 lbs.
	Area.	Area.	Area.
Balcarras Haigh Yard mine	112	56	84
Result	6·79 lbs.	8·65 lbs.	8·26 lbs.

And about a dozen more throughout Reports 2 and 3, in which the greatest effect has been produced by the minimum of area, leading therefore to the inference that a more restricted opening would have increased the value of the fuel. Taken as a whole, the only honest inference that can be drawn from the three Reports is, that the question sought to be solved by the Admiralty coal investigation remains exactly where it was for all practical purposes; the analyses, whether proximate, ultimate, or lithargic, together with the boiler experiments, being in all senses of the expression null, void, and of no effect or value whatever.

And as a proof of the little care taken to insure accuracy to the whole performance, we find at page 10, Report No. 3, that even the simplest rules of arithmetic have been violated in a Table purporting to show the average composition of the coals from Wales, Newcastle, Lancashire, Scotland, and Derbyshire. This table gives, or ought to give, the composition of the respective coals in 100 parts, and strange to say, the results do not amount to 100 in any single instance: the Welsh coal is more, and the others less than 100, though the oxygen was calculated from the loss.

LONDON, 18 *Upper Seymour-street*,
10th June, 1858.

A

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ARTS, MANUFACTURES, AND MINES.

ABIETINE. A pale yellow, transparent, viscid exudation from the *Abies pectinata*, a species of fir, growing in the neighborhood of Strasburg, and hence called Strasburg turpentine. It contains 35 per cent. of a volatile oil of an agreeable smell, combined with a resin, and a small quantity of the acid of amber, as well as the peculiar body called abietin, a resin of an acid kind, styled therefore by some abietic acid. If the indifferent resin be removed by absolute alcohol, and the remainder digested with carbonate of potash, an abietate of potash is obtained. It dissolves in petroleum, and crystallizes out of it. It resembles Canadian balsam, and is used for attaching microscopic objects to glass slips.

ACETAL, is the subacetate of ether; having for its chemical symbol 3 Ac O + Ac O_3. It is a light colorless ethereous liquid.

ACETATE. (*Acétate*, Fr.; *Essigsaure*, Germ.) Any saline compound of which the acetic is the acid constituent; as acetate of soda, of iron, of copper, &c.

ACETATE OF ALUMINA, see Red Liquor and Mordant; of Copper, see Copper; of Iron, see Iron; of Lead, see Lead; of Lime, see Pyroligneous Acid.

ACETIC ACID, or, according to the new nomenclature of organic chemistry, *acetylic acid hydrate*, being a compound of the radical acetyl (Ac $C_4 H_3$) and oxygen (O_3), with water (H O), for it cannot be bought in the dry state. It is formed out of alcohol in the acetous fermentation, or by its oxygenation with air; it is produced in the dry distillation of most non-volatile organic compounds, as of wood, gum, starch, &c., in the spontaneous decomposition of the watery solutions of citric and tartaric acids, as also by the boiling of several organic substances with sulphuric acid. It exists ready formed in several vegetable and animal juices. See Gerhardt.

Alcohol is a compound which, even diluted with water and exposed to the air, is not liable to spontaneous change; but if in this state it is mixed with yeast, at a temperature of from 60° to 90° Fahr., it absorbs oxygen, and passes into acetic acid. The oxygen forms first water, with 2 atoms of the hydrogen of the ethyl, whereby acetyl is generated; therefore ethyloxide-hydrate (alcohol) becomes acetyloxide hydrate, (aldehyde), which by absorption of two more atoms of oxygen, constitutes hydrated acetic acid.

$$\begin{array}{rlcl}
 & \text{1 Atom Alcohol} & = & C_4H_5O + HO \\
- & \text{2 Atoms Hydrogen} & = & H_2 \\
 & = \text{Aldehyde} & & \overline{C_4H_3O + HO} \\
+ & \text{2 Atoms Oxygen} & & O_2 \\
= & \text{Acetic Acid Hyd.} & & \overline{C_4H_3O_3 + HO.}
\end{array}$$

Its atomic weight on the hydrogen scale is therefore 60 in the state of hydrate, and 51 dry.

Albumen, gluten, and vegetable matters which contain these substances, such as the juice of beet-roots, operate also the oxidation of alcohol, and that the more rapidly, the more ample the exposure of the mixture to the air. While sugar is transmuted into carbonic acid, and alcohol only through the intervention of gluten, alcohol suffers that change by contact with finely divided platinum. It is hence probable, that to what is called acetous fermentation, the vital action of the particles of yeast is not indispensable, and that it belongs rather to the category of chemical combustion; *to the contact action of Liebig, the catalysis of Berzelius*, or the *polar combination of Löwig.*

In the vinegar of wine, malt, or that in which organic matter has been infused, there appears a peculiar mould-plant, belonging to the genus *Mycoderma* Pers.; which is usually called *vinegar mother.* As the plant grows, it decomposes the acid, and leaves eventually nothing but water. It contains proteine, and consequently azote, but leaves no ashes when burned.

The same circumstances which govern the conversion of alcohol into vinegar, preside over that of wood spirit into formic acid (acid of ants), fusel oil (oil of grain) into valerianic acid; and probably butyric acid has some such organ. With regard to the formation of vinegar, M. Dumas observes that every fermentation has for its effect to dissociate a compound into a more simple state; but the so-called acetous fermentation unites alcohol or aldehyde with the oxygen of the air; being the only case in which fermentation represents a true combination. He admits, notwithstanding, that this fermentation, in a certain point of view, possesses the character of the other fermentive actions, namely, the concourse of an organized substance, and of an organic matter; the one being a ferment (the mother), and the other fermentable. The conversion of alcohol into vinegar never happens in common cases, without the aid of an albuminous substance, and of circumstances favorable to all fermentations, such as the presence of air, not only at its commencement, but during its entire course.

The lactic fermentation has however been sometimes mistaken for the acetous; but it may be distinguished by its requiring no alcohol, but only starchy or saccharine matters; and after it begins, exposure to air is not needed. It has been supposed that acetification is analogous to nitrification, as to the utility of porous bodies which divide the liquid and the air; thus ammonia passed along with air through platinum sponge, gently ignited in a tube, produces nitric acid; and pumicestone, in like circumstances, combines sulphurous acid and oxygen into the sulphuric; and so we have seen that a mixture of alcohol vapor and air under the influence of the same sponge is converted by a true oxidation of the ether (of the alcohol), first into aldehyde, and afterwards into acetic acid. A like oxidation takes place in the wine or beer, which being purposely left in casks partially filled, rises by capillarity on the wood above the liquid level, and is there subjected to the porous influence. The vinegar is much more rapidly generated, however, by the various artificial methods of multiplication of points of contact with the air, presently to be described.

Vinegars may be arranged under four heads: 1. Malt or sugar vinegar; 2. Wine and fruit vinegar; 3. Alcohol vinegar; 4. Wood vinegar.

1. *Malt vinegar* is manufactured most extensively in the United Kingdom, chiefly in England, to the amount of fully 3,000,000 of gallons, on which an excise duty of 2*d.* per gallon is levied, and for the license to manufacture it, 5*l.* annually must be paid. The total number of vinegar manufactories in this country is about fifty, of which five of the principal ones are in London, and these carry on at the same time the manufacture of British wines, now happily emancipated from the trammels of the Excise. From 6 bushels of malt, properly crushed, 100 gallons of wort in whole may be extracted by due mashing, the first water of infusion being of the temperature of 160° Fahr., and the next two progressively hotter, for exhausting the soluble saccharine matter. When the wort is cooled to 75°, from 3 to 4 gallons of good yeast are stirred into it in the fermenting tun, and when it has been in brisk fermentation for about 40 hours, it is racked off into used vinegar casks, laid upon their sides in a room heated with a stove for quick work; or otherwise, during summer, in the open air, under exposure to the sun. The casks should be only about ¾ filled, and left unclosed, or loosely covered from the rain at their bung holes, to favor the free acidifying action of the atmosphere. In the air, the acetic fermentation may not be completed till after the lapse of three months; but in stove-rooms in much shorter time, according to the temperature. The sour liquor is then transferred from the several casks by means of a flexible pipe, and pumped into the stove-vat, whence it is run into the clarifying and flavoring casks, called "rapes," being here made to filter slowly and repeatedly through condensed heaps of the stalks and skins of raisins, called rape, which is the refuse of the British wine manufacture. Vinegar thus made contains always a considerable quantity of gluten, and is therefore liable to become mouldy and to putrify; to counteract which, a certain portion of sulphuric acid may be legally, and is always, mixed with British-made vinegar; but that portion is too often overpassed through avarice, and is certainly injurious to health. I have found by analysis in a sample of vinegar, made by one of the most eminent London manufacturers, with which he supplies the public, no less than 175 grains of the strongest oil of vitriol per gallon, added to vinegar containing only 3·6 per cent. of real acetic acid; giving it an apparent strength after all of only 4 per cent.; whereas standard commercial vinegar is rated at 5 per cent. It is a remarkable fact, that the people of this country have had their vinegar palate so depraved, that they prefer the vitriolized vinegar to the pure; and that all attempts at introducing a better article into general sale has proved abortive,—a fact discreditable to our nation, of which several instances have come before me.

The complete acidification of malt wort by the above process being very slow, has given rise to many projects, more or less successful, for accelerating it. So long ago as the year 1824, Mr. Ham, of Norwich, obtained a patent for exposing worts to the

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atmospheric air upon a most extensive surface, by means of a revolving pump, which caused a constant shower of it to fall upon and through a bundle of birch twigs supported in the middle of a large tun. The air had free access to the twigs. The wash, being kept at a temperature of from 90° to 100° Fahr., by steam pipes at the bottom of the tun, and continually repumped, became moderately acetified in 48 hours, and was finished into good vinegar, either by that process, or preferably by racking off into casks, and exposing it in them to a temperature of 85° Fahr. for 15 or 20 days. He also found that a wort made with 1 part of malt mixed with 6 of raw barley, properly mashed, afforded by this means an excellent vinegar. A wort of sp. gr. 1·060 (60 excise gravity) will yield a vinegar of revenue proof, or of 5 per cent. of real acetic acid. This quick process belongs rather to the combustion class of chemical transformations than to that of the fermentative, as yeast is not essential, though it is found to prove serviceable, as in the corresponding formation of acetic acid from the oxygenation of alcohol some stale vinegar is used as a ferment, or as a contact agent.

Under Messrs. Ham's instructions four considerable manufactories of vinegar have been established, with the products of two of which I am practically conversant, and I am warranted by experimental proofs in declaring that the vinegar made by Messrs. Hill, Evans, and Williams, of Worcester, and Messrs. Hills and Underwood, of Norwich and Eastcheap, London, are perfect specimens of acetic acid for family use, and also for manufacturing purposes. The latter company liberally displayed, in the South Gallery of the Royal Exhibition, at No. 7. Class 3. substances used as food, a model of their acetifying apparatus, as mounted in their works.

An excellent vinegar may be made for domestic purposes by adding to a syrup consisting of one pound and a quarter of sugar for every gallon of water, a quarter of a pint of good yeast. The liquor being maintained at a heat of from 75° to 80° Fahr., acetification will proceed so well that in 2 or 3 days it may be racked off from the sediment into the ripening cask, where it is to be mixed with 1 oz. of cream of tartar, and 1 oz. of crushed raisins. When completely freed from the sweet taste, it should be drawn off clear into bottles, and closely corked up. The juices of currants, gooseberries, and many other indigenous fruits, may be acetified either alone, or in combination with syrup. Vinegar made by the above process from sugar should have fully the revenue strength. It will keep much better than malt vinegar, on account of the absence of gluten, and at the present low price of sugar will not cost more, when fined upon beech chips, than 1*s.* per gallon.

2. *Wine vinegar* is made of the best quality, and on the greatest scale, at Orleans in France, out of wines which have become more or less acidulous, and are, therefore, of inferior value. When the vinegar is made from well-flavoured wines, it is preferable to every other for the use of the table. The old method pursued in the *vinaigreries* consists merely in partially filling a series of large casks placed in 3 or 4 ranges over each other in a cellar warmed with a stove to the temperature of 85° Fahr., with the wine mixed with a certain proportion of ready-made vinegar as a ferment. More wine is added in successive small portions as fast as the first has become acetified, taking care that a free ventilation be maintained, in order to replace the carbonic acid produced by fresh atmospheric oxygen. In summer, under a favorable exposure of the windows and walls of the fermenting room to the sun, artificial heat is not needed. Each cask is of about 60 gallons capacity, and the whole set is filled up ⅓ with vinegar, to which 2 galls. of wine are added, and weekly afterwards 2 galls. more. About 8 gallons are drawn off at the end of four weeks as vinegar, and then successive additions of wine are made as before to the casks. These are laid horizontally in rows upon their gawntrees, and are pierced at the upper surface of the front end with two holes: one, called the *eye*, is two inches in diameter, and serves for pouring in the charges through a tunnel; the other is a small air-hole alongside. The casks should never be more than ⅔ full, otherwise a sufficient body of air is not present in them for favouring rapid acetification. At the end of a certain period, the deposit of tartar and lees becomes so great, that the casks must be cleared out. This renovation usually takes place every ten years; but the casks, when made of well-seasoned oak and bound with iron hoops, will last 25 years. The wine as well as the vinegar produced should be clarified by being slowly filtered through beech chips closely packed in a large open tun. When wines are new, and somewhat saccharine, or too alcoholic, they acetify reluctantly, and need the addition of a little yeast or even water to the mixture; and when they are too weak, they should be enriched by the addition of some sugar or stronger wine, so as to bring them to a uniform state for producing vinegar of normal strength. To favour the renewal of fresh air into the upper part of the hogsheads, it would be advisable to pierce a two-inch hole near to the upper level of the liquid when the cask is fullest, by which means the heavy carbonic acid would fall out, and be replaced by the atmospheric air at the superior apertures.

I have had occasion to examine professionally the best wine vinegars imported into this country from Orleans, and I found their specific gravity to be about 1·019, and their percentage of acetic acid hydrate (crystalline acid) to be from 6½ to nearly 7. One or two samples were supposed to contain acetified cider. This adulteration may be tested by neutralizing the vinegar with ammonia, and then adding solution of acetate of lime. Tartrate of lime is of course precipitated from the wine vinegar, while the pearly malic acid of the cider affords no precipitate with the lime, but may be detected by acetate of lead, by the glistening pearly scales of malate of lead, hardly soluble in the cold.

3. *Alcohol Vinegar.*—This species has been hitherto manufactured chiefly in Germany, having commenced soon after Döbereiner's fine discovery of the combustion of alcohol into acetic by the agency of *platinum mohr.* Under a large glass bell, he placed on shelves, an inch or two apart, several saucers, containing spirits of wine, with slips of blotting paper so suspended as that their lower edges dipped in the spirits. Over and alongside of these saucers, other smaller ones were set, containing the black platinum powder moistened with the spirits. The apparatus being exposed to the sunshine, or even put into an apartment moderately warm, a copious formation of vapours takes place, with a manifest increase of temperature, and streaks of condensed fluid run down the sides of the bell into the subjacent basin. This fluid is acetic acid, resulting from the acidification of the elements of the alcohol by the oxygen of the atmospherical air included. This interesting transformation ceases with the exhaustion of the oxygen, but it may be renewed from time to time by renovation of the air. One atom of alcohol $= C_4 H_5 O + H O = 46$ parts; in which compound, two atoms of hydrogen being replaced by two of oxygen, we have $46 + 14 = 60$ parts, or one atom of hydrated acetic acid. Hence we see that 46 parts of absolute alcohol afford 60 of radical vinegar; 100 parts therefore afford 130, and require for this conversion nearly 70 parts of oxygen, allowing two atoms of oxygen for the abstraction of the two atoms of hydrogen. Since air in round numbers contains a little more than one fifth its volume of oxygen, then 1000 cubic inches wil contain upwards of 200 of oxygen, which will weigh fully 70 grains, being the quantity requisite for the transformation of 100 grains of alcohol into acetic acid in the above process. Two atoms of water are also formed, equal to 18 grains. In practice it is found that weak alcohol answers best. With a box of 12 cubic feet capacity, and with 7 or 8 ounces of platinum mohr properly distributed, 1 lb. of alcohol may in the course of a day be converted into pure vinegar, fit for every purpose of the kitchen or the chemist. I have examined the vinegar manufactured from spirits, and found it to be excellent, as it contains no gluten, and it is therefore not liable to change. It is not possible in this way to make a strong acetic acid, nor can it be made at all on the large scale in this country, on account of our revenue laws.

In the sequel of Döbereiner's discovery, another German chemist, M. Schutzenbach, applied the principle of oxygenation to beers and other alcoholic liquors, for the purpose of converting them rapidly into vinegar; and about the same time M. Wagenmann contrived his *graduator*, or *essigbildder*, a simple apparatus for the quick vinegar manufacture. It consists of an oaken tub 5½ feet high, 3½ feet wide, and 3 feet at bottom, set upon a wooden frame about 14 inches from the floor. Fifteen inches above the bottom, the tub is pierced with a horizontal row of eight equidistant holes, one inch in diameter. Five inches beneath the mouth of the tub a strong beechwood hoop is fastened to the inner surface, in order to support a circular oaken shelf, the space round the edge of which is stuffed tight with hemp. This shelf is perforated with at least 400 gimlet holes of about ⅛ of an inch, through each of which a porous cotton wick is let down several inches, hanging by a knot in the top of the hole at its upper end. In the same circular shelf there are 4 holes, 1½ inch in diameter, and 18 inches apart, into each of which is fixed tight the middle of a stout glass tube about 4 inches long. These tubes favour the circulation of the air admittted by the circumferential holes. One inch above the bottom of the tub a hole is pierced for the reception of a syphon of discharge, the top curvature of which must stand about 1 inch below the holes in the side of the tub, to prevent the liquor collected, to the depth of about 12 inches on the bottom, being spilled. Into the empty space over this liquor, the bulb of a thermometer is placed, while the stem and scale project to show the interior temperature. Beneath the lower outer leg of the syphon a reception cistern is set. The mouth of the tub has a wooden lid, with a funnel fixed in its middle for the introduction of the liquor to be acetified. The whole capacity of this tub from the bottom up to within 1 or 2 inches of the perforated shelf, is to be filled up with shavings of beech-wood (previously boiled in water), or with grape stalks, or birch-twigs, all well soaked with vinegar. This apparatus being placed in an apartment, heated to from 80° to 100° Fahr., is to have its uppermost compartment filled with liquor. This slowly filters down through the cotton wick threads, thence over the surfaces of the chips or stalks, and finally into the subjacent receiver, having been exposed in its transit very freely to the air. The ordinary acetifying mixture consists of 8 parts of proof spirits, 25 parts of river water, 15 parts of good vinegar, and 15 parts of clear beer or wine. The water should be heated to about 150° before the other ingredients are added to it, whereby the mixture acquires a genial temperature. After this has been all transmitted through the apparatus, it will be found imperfectly acetified, and therefore must be passed through once or twice more. And since the more alcohol that is present the slower is the process, it is advisable to keep back part of the spirits at first, and to add it in the subsequent transmissions. The wash-cistern, which contains the acetifying mixture, should be supported on a shelf near the ceiling of the stove-heated apartment, in order to be kept constantly warm. After the first operation is completed, the interior of the cask becomes so active an oxidizer, that the addition of vinegar to the mixture is no longer necessary; but care should always be taken to have it as well clarified as possible, in order to prevent the depositing of much gluten upon the beech-chips. Dr. Kastner prescribes the following manner of making a malt wine for the quick vinegar process:—Crush together 80lbs. of pale barley malt, and 40lbs. of pale wheat malt, and infuse them in 100 quarts of water of 122° Fahr., and afterwards mash them properly with 300 quarts of hotter water. The wort thus made is to be cooled, drawn off from the grains, fermented with yeast for 3 days, then the beer is to be barrelled up for use.

I have already adverted to the quick acetification of malt-wort by Mr. Ham's patent process. This has been mounted upon a large scale of late years, the air for oxygenating the alcohol of the wash, previously fermented with yeast, having been supplied from two gasometers, alternately moved by steam-engine power. Two circumstances attend this quick process; which are, that as the materials are not thoroughly acetified, the product must be left for some time to ripen in casks, and the resulting vinegar has not the flavor of that slowly made in the old way. I am informed that a vinegar, equivalent not merely to 5½ per cent. has been produced, but one five times stronger, by operating with an apparatus 13 feet high, 14 wide at bottom, and 15 at top, in which an adequate temperature was generated during the oxidation of the great mass of materials, without artificial warmth.

3. *Chemical process.*—Acetic acid from the pure acetate of soda is formed as follows: —100 lbs. of the pulverized salt being put into a hard glazed stoneware receiver, or deep pan, from 35 to 36 lbs. of concentrated sulphuric acid are poured in one stream upon the powder, so as to flow under it. The mixture of the salt and acid is to be made very slowly, in order to moderate the action and the heat generated as much as possible. After the materials have been in intimate contact for a few hours, the decomposition is effected; sulphate of soda in crystalline grains will occupy the bottom of the vessel, and radical vinegar, or acetic acid (hydrate), the upper portion, partly liquid and partly in crystals. A small portion of pure acetate of lime, added to the acid, will free it from any remainder of sulphate of soda, leaving only a little acetate in its place; and though a small portion of sulphate of soda may still remain, it is unimportant, whereas the presence of any free sulphuric acid would be very injurious. This is easily detected by evaporating a little of the liquid, at a moderate heat, to dryness, when that mineral acid can be distinguished from the neutral soda sulphate. This plan of superseding a troublesome distillation, which is due to M. Mollerat, is one of the greatest improvements in this process, and depends upon the insolubility of the sulphate of soda in acetic acid. The sulphate of soda thus recovered, and well drained, serves anew to decompose acetate of lime; so that nothing but this cheap earth is consumed in carrying on the manufacture. To obtain absolutely pure acetic acid, the above acid has to be distilled in a glass retort. That acid, in its crystallizable state, boils at 230° Fahr., or 110° C., by my experiments made with a pure acid prepared by M. Lemire, of Paris: others have rated its boiling point 114° and even 120° C.

The following table of the specific gravities of acetic acid, of successive strengths, is the result of a series of experiments made by me in Glasgow in May, 1819; the liquid crystallizable hydrate being reckoned 100:—

Acid.	Sp. Gr.	Acid.	Sp. Gr.	Acid.	Sp. Gr.
100	1 ·0620	76	1 ·0743	52	1 ·0617
98	1 ·0650	74	1 ·0740	50	1 ·0603
96	1 ·0680	72	1 ·0733	45	1 ·0558
94	1 ·0700	70	1 ·0725	40	1 ·0512
92	1 ·0715	68	1 ·0716	35	1 ·0459
90	1 ·0728	66	1 ·0712	30	1 ·0405
88	1 ·0730	64	1 ·0701	25	1 ·0342
86	1 ·0735	62	1 ·0687	20	1 ·0282
84	1 ·0738	60	1 ·0675	15	1 ·0213
82	1 ·0740	58	1 ·0665	10	1 ·0147
80	1 ·0750	56	1 ·0647	5	1 ·0075
78	1 ·0748	54	1 ·0634		

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In *Berzelius Jahres berichte* xvi. 192, the table of Van der Toom is given for the successive quantities of dry acetic acid, corresponding to successive densities. He rates the sp. gr. of the hydrate at 1·0570, being the acid which contains 85·11 of dry acid. In my table, the equivalent hydrate is marked 1·062, a gravity as low as is probably to be obtained by weighing a solution of the drained crystals. An acid of 1·0698 contains, according to him, 51 of the dry; while an acid of 1·0675 corresponds, in my table, to 60 of the hydrate, or 51 of dry acid. In general his gravities are a little greater than mine at corresponding degrees of acid strength. The above numbers in my table are experimental, not interpolated from a few points, and may, I hope, be relied upon. The greatest density seems to be produced when two atoms of water = 18 are mixed with one of the hydrate = 60, or 23 with 77, at which dilution the differences of density are very small, and minute errors may have occurred. When 6 atoms of water are added to one of the hydrate, making 7 atoms of water in all, then the acid acquires its primitive liquid density of about 1·062. A curious analogy exists in this respect with nitric acid, which suffers the greatest degree of condensation, in the series of its dilutions, when one atom of the real acid is combined with 7 atoms of water.

Pure acetic acid possesses a peculiar pungent, though not disagreeable smell, and a strongly acid taste. It crystallizes in needles and plates when cooled to 55° Fahr., and melts when heated to 61°. The specific gravity of the crystals (taken by means of spirits of turpentine) I found to be 1·135 at 55° Fahr. The vapor of the boiling acid is highly combustible, and burns with a blue flame. Acetic acid hydrate dissolves camphor, gliadine, resins, the fibrine of blood, and several organic compounds. When its vapor is conducted through a slightly ignited porcelain tube, it is converted entirely into carbonic acid and aceton, an atom of the acid being resolved into an atom of each of the resultants. At a white heat, the vapor is converted into carbonic acid, carburetted hydrogen, and water. The acetates comport themselves at elevated temperatures differently, according to the strength of affinity between the acid and the base. When this is weak the acid escapes unchanged, and the stronger it is, the more acid is converted into aceton. Acetate of barytes affords most of this spirituous liquor, and next to it the alkaline acetates and acetate of lead.

Acetate of copper yields, at a heat of 400° or 500°, a concentrated acetic acid, mixed with some aceton. This process was formerly employed for preparing radical vinegar, as also that of decomposing that of acetate of lead, by sulphuric acid; but both are now renounced for the process by acetate of soda above described.

Acetic acid is a pretty stable compound, as is evinced by its compound with soda and potash, bearing the heat of 600° Fahr. without decomposition. Acetate of potash and soda, dissolved in much water, readily mould and decompose; but acetate of ammonia is not liable to change in close vessels. When acetic acid is distilled along with peroxide of manganese and sulphuric acid, it is converted into formic acid. Iodic acid has the same effect with precipitation of iodine: it reduces gold from its chloride without disengagement of carbonic acid; but it does not reduce mercury from its nitrate or sulphate, as formic acid does.

The simplest reagent for purifying common vinegar is recently calcined wood charcoal in fine powder; with which it may be digested, or, what is better, distilled, whereby a portion of the water comes over first, and may be got rid of, while the stronger vinegar is a later product. Attempts are often made to give wood vinegar the flavor of that made from wine, by adding acetic ether, wine, &c., but never with complete effect. The best disguise is obtained by mixing in some highly flavored Orleans vinegar. Malt vinegar prepared by very slow fermentation in the air, acquires a peculiar ethereous odor, which cannot be imitated artificially, and hence persons accustomed to the flavor of such vinegar, by itself or in pickles, do not relish the vinegar made by the quick oxidizement process, either from malt or spirits. Even subjecting this vinegar to the action of rape accomplishes imperfectly the object in view.

Were vinegar pure, it would be valued by its specific gravity alone, which at all strengths under 50 per cent. gives exact indications; but this is seldom the case, for ordinary vinegar contains more or less gluten and other organic matter, such as caramel, or burnt sugar, to color and flavor it, besides sulphuric and possibly other acids. Hence the Excise have adopted the following plan of acetometry suggested by Messrs. Taylor. When pure vinegar is saturated with quicklime, the liquid takes a density double of that due to the acetic acid present. Thus, an acetate of lime of sp. gr. 1·018, corresponds to a pure vinegar of 1·009; but malt vinegar of that strength has its density raised to 1·014 by the gluten. When such vinegar is saturated with quicklime, the acetate acquires a specific gravity of 1·023, from which, if the five due to the gluten be deducted, the remainder, 1·018, will be double of the true density. Revenue proof vinegar, called No. 24, has, according to these gentlemen, the

Sp. gr.	1·0085,	and contains	of real acid	5 in 100.
Do.	1·0170	do.	do.	10 do.
Do.	1·0257	do.	do.	15 do.
Do.	1·0320	do.	do.	20 do.
Do.	1·0470	do.	do.	30 do.
Do.	1·0580	do.	do.	40 do.

The acid of this table is the anhydrous, being stronger by about 15 per cent. than that of my table given above. The chemical analysis of vinegar consists first in determining the presence and proportion of foreign matter. With this view 500 grains of it should be evaporated by the heat of a chlor-calcium bath, the residuum weighed and examined. If it be sour, sulphuric acid may be suspected, and its amount be ascertained by precipitation with nitrate of barytes, and weighing the washed and dried precipitate. Every 118 parts indicate 49 of oil of vitrol; but if saline sulphates be present, their amount may be ascertained by igniting the above residuum and weighing what remains. The loss in ignition will be due to organic matter, acetates, and sulphuric acid. If an alkaline acetate be present after ignition, the residuum may be an alkaline carbonate. Nitric acid is best detected by adding a few drops of a dilute sulphate of indigo to the vinegar, and by boiling the mixture; when the blue will pass into a dirty brown yellow if nitric acid be present. In common cases a ready mode of estimating the strength of the vinegar is wanted, and no reagent is better for the purpose than the bicarbonate of potash, two grains of which are equivalent to very nearly one of anhydrous acetic acid. To 100 or 1000 grs. of the vinegar in question we have only to add from a weighed parcel of pounded bicarbonate of potash, enough to produce neutralization by the test of litmus paper, and the half number of grains required denotes the number of grains of acetic acid in 100 or 1000 of the vinegar. Or a normal solution of the bicarbonate may be kept ready made, of which 1000 water grain measures contain 100 of the salt; then each 20 grain measures expended in neutralizing 1000 water grain measures of the vinegar denote one grain of real acetic acid. As the extrication of carbonic acid from the bicarbonate is apt, however, in common hands to cause fallacies, I prefer ammonia as a general acidimetrical test, of which 1000 water grain measures of specific gravity 0·992 neutralize exactly one atom of acetic acid; that is, 51 grains of the anhydrous, or 60 of the hydrate; therefore after adding that test ammonia to the vinegar faintly reddened with litmus, out of a graduated glass tube, till the neutral tint of color be hit, the number of water grain measures of test expended, being multiplied either by 51 or 60, will give for a product the per centage of anhydrous or hydrated acetic acid. This is the method I have pursued for very many years, and which gives results of perfect precision in a few minutes.

Vinegar is so extensively employed as a condiment, that it should be of better quality than is commonly on sale in the United Kingdom, where it is almost always contaminated with oil of vitriol. All our pickles participate in the same noxious ingredient. The fumes of vinegar, and even its odor, as in the vinegar of the Three Thieves of Marseilles, were long supposed to be counteractive of contagion in sick rooms; but they are rather injurious, by covering unwholesome smells from want of due cleanliness and ventilation, and should never be relied upon. In combination with alumina, and also with oxide of iron, it is extensively used in the dyeing and printing of cotton, under the names of red liquor and iron liquor, as mordants for bright and dark colors.

According to Döbereiner and Liebig, in the conversion of alcohol into acetic acid no carbonic acid is formed. 100 lbs. of alcohol consisting of 52·6 carbon + 12·9 hydrogen + 34·5 oxygen, absorb from the air, in the process of acetification, 35·2 lbs. of oxygen, which abstract 4·4 lbs. of hydrogen from the alcohol, and thus generate 39·6 lbs. of water, leaving the substance called aldehyde (dehydrogenated alcohol), which consists of 52·6 carbon + 8·5 hydrogen + 68·4 oxygen.

In practice we cannot obtain so much acid as the above, but the theoretical maximum serves as a beacon, and the nearer we can approach to it the better. About 3600 cubic feet of air contain 69 lbs. of oxygen, the quantity barely necessary for acetifying 100 lbs. of alcohol; but as the air is only partially stripped of that element, much more is needed, and this excessive current carries off some alcohol, aldehyde, and acetic acid, and so lessens the product. If, on the other hand, air be too sparingly supplied, volatile aldehyde is chiefly formed, which flies off, and leaves a mawkish putrefying liquor of no value.

We may complete the preceding view of the production of acetic acid, by showing the relations which subsist between it and sugar, and starch, through the medium of alcohol—four correlative compounds, 100 lbs. of cane sugar are convertible into 100 lbs. of starch sugar or grape sugar, by boiling it with sulphuric or tartaric acid, and abstracting the acid by means of chalk; and that weight of either kind of sugar is capable of yielding by fermentation, 53·7 lbs. of alcohol. 100 lbs. of starch, if well saccharified, should afford fully 100 lbs. of starch sugar, and, therefore, 53·7 lbs. alcohol. These are the theoretical quantities, but they can never be realized in practice.

A quarter of good malt, weighing 320 lbs., contains by my experiments 144 solid extract, which should yield, first, 69½ alcohol; and next 100 lbs. of acetic acid hydrate, equivalent to 17 times that weight of revenue proof vinegar = 170 gallons nearly.

Before the process for pyroligneous acid, or wood vinegar, was known, there was only one method of obtaining strong vinegar practised by chemists; and it is still followed by some operators, to prepare what is called radical or aromatic vinegar. This consists in decomposing, by heat alone, the crystallized binacetate of copper, commonly, but improperly, called distilled verdigris. With this view, we take a stoneware retort (*fig.* 1), of a size suited to the quantity we wish to operate upon; and coat it with a mixture of fire clay and horsedung, to make it stand the heat better. When this coating is dry, we introduce into the retort the crystallized acetate slightly bruised, but very dry; we fill it as far as it will hold without spilling when the beak is considerably inclined. We then set it in a proper furnace. We attach to its neck an adopter pipe, and two or three globes with opposite tubulures, and a last globe with a vertical tubulure. The apparatus is terminated by a Welter's tube, with a double branch; the shorter issues from the last globe, and the other dips into a flask filled with distilled vinegar. Everything being thus arranged, we lute the joinings with a putty made of pipeclay and linseed oil, and cover them with glue paper. Each globe is placed in a separate basin of cold water, or the whole may be put into an oblong trough, through which a constant stream of cold water is made to flow. The tubes must be allowed a day to dry. Next day we proceed to the distillation, tempering the heat very nicely at the beginning, and increasing it by very slow degrees till we see the drops follow each other pretty rapidly from the neck of the retort, or the end of the adopter tube. The vapors which pass over are very hot, whence a series of globes are necessary to condense them. We should renew, from time to time, the water of the basins, and keep moist pieces of cloth upon the globes; but this demands great care, especially if the fire be a little too brisk, for the vessels become, in that case, so hot, that they would infallibly be broken, if touched suddenly with cold water. It is always easy for us to regulate this operation, according to the emission of gas from the extremity of the apparatus. When the air bubbles succeed each other with great rapidity, we must damp the fire.

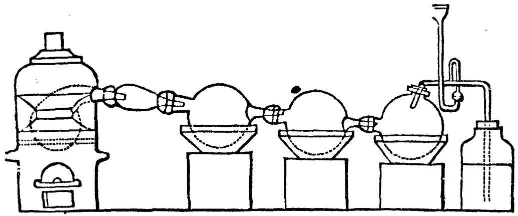


Fig. 1.

The liquor which passes in the first half hour is weakest; it proceeds, in some measure, from a little water sometimes left in the crystals, which when well made, however, ought to be anhydrous. A period arrives towards the middle of the process when we see the extremity of the beak of the retort, and of the adopter, covered with crystals of a lamellar or needle shape, and of a pale green tint. By degrees these crystals are carried into the condensed liquid by the acid vapors, and give a color to the product. These crystals are merely some of the cupreous salt forced over by the heat. As the process approaches its conclusion, we find more difficulty in raising the vapors; and we must then augment the intensity of the heat, in order to continue their disengagement. Finally, we judge that the process is altogether finished, when the globes become cold, notwithstanding the furnace is at the hottest, and when no more vapors are evolved. The fire may then be allowed to go out, and the retort to cool.

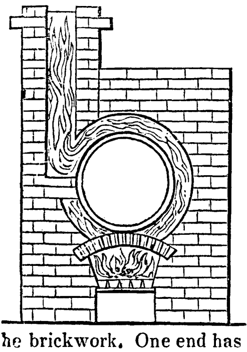
As the acid thus obtained is slightly tinged with copper, it must be rectified before bringing it into the market. For this purpose we may make use of the same apparatus, only substituting for the stoneware retort a glass one, placed in a sand bath. All the globes ought to be perfectly clean and dry. The distillation is to be conducted in the usual way. If we divide the product into thirds, the first yields the feeblest acid, and the third the strongest. We should not push the process quite to dryness, because there remain in the last portions certain impurities, which would injure the flavor of the acid.

The total acid thus obtained forms nearly one half of the weight of the acetate employed, and the residuum forms three tenths; so that about two tenths of the acid have been decomposed by the heat, and are lost. As the oxyde of copper is readily reduced to the metallic state, its oxygen goes to the elements of one part of the acid, and forms water, which mingles with the products of carbonic acid, carbureted hydrogen, and carbonic oxyde gases which are disengaged: and there remains in the retort some charcoal mixed with metallic copper. These two combustibles are in such a state of division, that the residuum is pyrophoric. Hence it often takes fire the moment of its being removed from the cold retort. The very considerable loss experienced in this operation has induced chemists to try different methods to obtain all the acid contained in the acetate. Thus, for example, a certain addition of sulphuric acid has been prescribed; but, besides that the radical vinegar obtained in this way always contains sulphurous acid, from which it is difficult to free it, it is thereby deprived of that spirit called the *pyroacetic*, which tempers the sharpness of its smell, and gives an agreeable aroma. It is to be presumed, therefore, that the preceding process will continue to be preferred for making aromatic vinegar. Its odor is often further modified by essential oils, such as those of rosemary, lavender, &c.

4. *Pyroligneous Acid, or Wood Vinegar.*—The process for making this acid is founded upon the general property of heat, to separate the elements of vegetable substances, and to unite them anew in another order, with the production of compounds which did not exist in the bodies subjected to its action. The respective proportion of these products varies, not only in the different substances, but also in the same substance, according as the degree of heat has been greater or less, or conducted with more or less skill. When we distil a vegetable body in a close vessel, we obtain at first the included water, or that of vegetation; there is next formed another portion of water, at the expense of the oxygen and hydrogen of the body; a proportional quantity of charcoal is set free, and, with the successive increase of the heat, a small portion of charcoal combines with the oxygen and hydrogen to form acetic acid. This was considered, for some time, as a peculiar acid, and was accordingly called *pyroligneous* acid. As the proportion of carbon becomes preponderant, it combines with the other principles, and then some empyreumatic oil is volatilized, of little color, but which becomes thicker, and of a darker tint, always getting more loaded with carbon.

Several elastic fluids accompany these different products. Carbonic acid comes over, but in small quantity, much carburreted hydrogen, and, towards the end, a considerable proportion of carbonic oxyde. The remainder of the charcoal, which could not be carried off in these several combinations, is found in the retort, and preserves, usually, the form of the vegetable body which furnished it. Since mankind have begun to reason on the different operations of the arts, and to raise them to a level with scientific researches, they have introduced into several branches of manufacture a multitude of improvements, of which, formerly, they would hardly have deemed them susceptible. Thus, in particular, the process for carbonizing wood has been singularly meliorated, and in reference to the preceding observations, advantage has been derived from several products that formerly were not even collected.

Fig. 2.



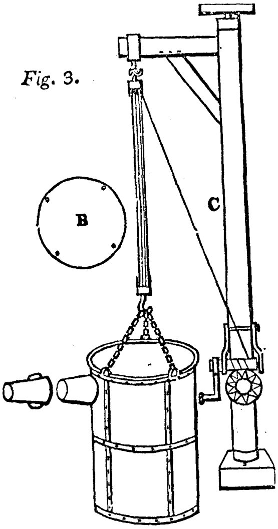
The apparatus employed for obtaining crude vinegar from wood, by the agency of heat, are large iron cylinders. In this country they are made of cast iron, and are laid horizontally in the furnace; in France, they are made of sheet iron riveted together, and they are set upright in the fire. *Fig.* 2 will give an accurate idea of the British plan, which is much the same as that adopted for decomposing pit coal in gas works, only that the cylinders for the pyroligneous acid manufacture are generally larger, being frequently 4 feet in diameter, and 6 or 8 feet long, and built horizontally in brickwork, so that the flame of one furnace may play around two of them. It would probably answer better, if their size were brought nearer the dimensions of the gas-light retorts, and if the whole system of working them were assimilated to that of coal gas.

The following arrangement is adopted in an excellent establishment in Glasgow, where the above large cylinders are 6 feet long, and both ends of them project a very little beyond the brickwork. One end has a disc or round plate of cast iron, well fitted, and firmly bolted to it, from the centre of which disc an iron tube, about 6 inches diameter, proceeds and enters, at a right angle, the main tube of refrigeration. The diameter of this tube may be from 9 to 14 inches, according to the number of cylinders. The other end of the cylinder is called the mouth of the retort; this is closed by a disc of iron, smeared round its edge by clay lute, and secured in its place by fir wedges. The charge of wood for such a cylinder is about 8 cwt. The hard woods—oak, ash, birch, and beech—are alone used; fir does not answer. The heat is kept up during the day-time, and the furnace is allowed to cool during the night. Next morning the door is opened, the charcoal removed, and a new charge of wood is introduced. The average product of crude vinegar called pyroligneous acid, is 35 gallons. It is much contaminated with tar, is of a deep brown color, and has a sp. gr. of 1·025. Its total weight is therefore about 300 lbs., but the residuary charcoal is found to weigh no more than one fifth of the wood employed; hence nearly one half of the ponderable matter of the wood is dissipated in incondensable gases Count Rumford states, that the charcoal is equal in weight to more than four tenths of the wood from which it is made. The count's error seems to have arisen from the slight heat of an oven to which his wood was exposed in a glass cylinder. The result now given, is the experience of an eminent manufacturing chemist.

The crude pyroligneous acid is rectified by a second distillation in a copper still, in the body of which about twenty gallons of viscid tarry matter are left from every 100. It has now become a transparent brown vinegar, having a considerably empyreumatic smell, and a sp. gr. of 1·013. Its acid powers are superior to those of the best household vinegar, in the proportion of three to two. By redistillation, saturation with quicklime, evaporation of the liquid acetate to dryness, and conversion into acetate of soda by sulphate of soda, the empyreumatic matter is so completely dissipated, that on decomposing the pure acetate of soda by sulphuric acid, a perfectly colorless and grateful vinegar rises in distillation. Its strength will be proportionable to the concentration of the decomposing acid.

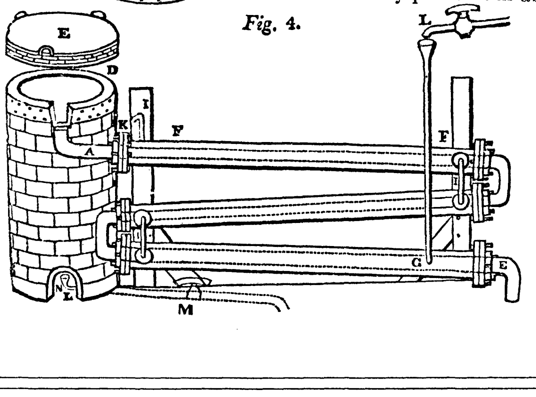
The acetic acid of the chemist may be prepared also in the following modes:—1. Two parts of fused acetate of potash, with one of the strongest oil of vitriol, yield, by slow distillation from a glass retort into a refrigerated receiver, concentrated acetic acid. A small portion of sulphurous acid, which contaminates it, may be removed by redistillation from a little acetate of lead. 2. Or four parts of good sugar of lead, with one part of sulphuric acid, treated in the same way, afford a slightly weaker acetic acid. 3. Gently calcined sulphate of iron, or green vitriol, mixed with sugar of lead, in the proportion of 1 of the former to 2½ of the latter, or with acetate of copper, and carefully distilled from a porcelain retort into a cool receiver, may be also considered an economical process. But that with binacetate of copper above described, is preferable to any of these.

Fig. 3.



The manufacture of pyroligneous acid is conducted in the following way in France. Into large cylindrical vessels (*fig.* 3) made of riveted sheet iron, and having at their top and side a small sheet iron cylinder, the wood intended for making charcoal is introduced. To the upper part of this vessel a cover of sheet iron, B, is adapted, which is fixed with bolts. This vessel, thus closed, represents, as we see, a vast retort. When it is prepared, as we have said, it is lifted by means of a swing crane, C, and placed in a furnace, D (*fig.* 4), of a form relative to that of the vessel, and the opening of the furnace is covered with a dome, E, made of masonry or brickwork. The whole being thus arranged, heat is applied in the furnace at the bottom. The moisture of the wood is first dissipated, but by degrees the liquor ceases to be transparent, and becomes sooty. An adopter tube, A, is then fitted to the lateral cylinder. This adopter enters into another tube at the same degree of inclination which commences the condensing apparatus. The means of condensation vary according to the localities. In certain works they cool by means of air, by making the vapor pass through a long series of cylinders, or sometimes, even, through a series of casks connected together; but most usually water is used for condensing, when it can be easily procured in abundance. The most simple apparatus employed for this purpose consists of two cylinders, F, F (*fig.* 4), the one within the other, and which leave between them a sufficient space to allow a considerable body of water to circulate along and cool the vapors. This double cylinder is adapted to the distilling vessel, and placed at a certain inclination. To the first double tube, F, F, a second, and

Fig. 4.



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sometimes a third, entirely similar, are connected, which, to save space, return upon themselves in a zigzag fashion. The water is set in circulation by an ingenious means now adopted in many different manufactories. From the lower extremity, G, of the system of condensers, a perpendicular tube rises, whose length should be a little more than the most elevated point of the system. The water, furnished by a reservoir, L, enters by means of the perpendicular tube through the lower part of the system, and fills the whole space between the double cylinders. When the apparatus is in action, the vapors, as they condense, raise the temperature of the water, which, by the column in L G, is pressed to the upper part of the cylinders, and runs over by the spout K. To this point a very short tube is attached, which is bent towards the ground, and serves as an overflow.

The condensing apparatus is terminated by a conduit in bricks covered and sunk in the ground. At the extremity of this species of gutter is a bent tube, E, which discharges the liquid product into the first cistern. When it is full, it empties itself, by means of an overflow pipe, into a great reservoir: the tube which terminates the gutter plunges into the liquid, and thus intercepts communication with the inside of the apparatus. The disengaged gas is brought back by means of pipes M L, from one of the sides of the conduit to the under part of the ash pit of the furnace. These pipes are furnished with stopcocks M, at some distance in front of the furnace, for the purpose of regulating the jet of the gas, and interrupting, at pleasure, communication with the inside of the apparatus. The part of the pipes which terminates in the furnace rises perpendicularly several inches above the ground, and is expanded like the rose of a watering can, N. The gas, by means of this disposition, can distribute itself uniformly under the vessel, without suffering the pipe which conducts it to be obstructed by the fuel or the ashes.

The temperature necessary to effect the carbonization is not considerable: however, at the last it is raised so high as to make the vessels red hot; and the duration of the process is necessarily proportional to the quantity of wood carbonized. For a vessel which shall contain about 5 meters cube (nearly 6 cubic yds.), 8 hours of fire is sufficient. It is known that the carbonization is complete by the color of the flame of the gas: it is first of a yellowish red; it becomes afterwards blue, when more carbonic oxyde than carbonic hydrogen is evolved; and towards the end it becomes entirely white,— a circumstance owing, probably, to the furnace being more heated at this period, and the combustion being more complete. There is still another means of knowing the state of the process, to which recourse is more frequently had; that is the cooling of the first tubes, which are not surrounded with water: a few drops of this fluid are thrown upon their surface, and if they evaporate quietly, it is judged that the calcination is sufficient. The adopter tube is then unluted, and is slid into its junction pipe; the orifices are immediately stopped with plates of iron and plaster loam. The brick cover, E, of the furnace is first removed by means of the swing crane, then the cylinder itself is lifted out and replaced immediately by another one previously charged. When the cylinder which has been taken out of the furnace is entirely cooled, its cover is removed, and the charcoal is emptied. Five cubic meters of wood furnish about 7 chaldrons (voies) and a half of charcoal. (For modifications of the wood-vinegar apparatus, see CHARCOAL and PYROLIGNEOUS ACID.)

The different qualities of wood employed in this operation give nearly similar products in reference to the acid; but this is not the case with the charcoal, for it is better the harder the wood; and it has been remarked that wood long exposed to the air furnishes a charcoal of a worse quality than wood carbonized soon after it is cut.

Having described the kind of apparatus employed to obtain pyroligneous acid, I shall now detail the best mode of purifying it. This acid has a reddish brown color; it holds in solution a portion of empyreumatic oil and of the tar which were formed at the same time, another portion of these products is in the state of a simple mixture: the latter may be separated by repose alone. It is stated above, that the distilling apparatus terminates in a subterranean reservoir, where the products of all the vessels are mixed. A common pump communicates with the reservoir, and sinks to its very bottom, in order that it may draw off only the stratum of tar, which, according to its greater density, occupies the lower part. From time to time the pump is worked to remove the tar as it is deposited. The reservoir has at its top an overflow pipe, which discharges the clearest acid into a cistern, from which it is taken by means of a second pump.

The pyroligneous acid thus separated from the undissolved tar is transferred from this cistern into large sheet iron boilers, where its saturation is effected either by quicklime or by chalk, the latter of which is preferable, as the lime is apt to take some of the tar into combination. The acid parts by saturation with a new portion of the tar, which is removed by skimmers. The neutral solution is then allowed to rest for a sufficient time to let its clear parts be drawn off by decantation.

The acetate of lime thus obtained indicates by the hydrometer, before being mixed with the waters of edulcoration, a degree corresponding to the acidimetric degree of the acid employed. This solution must be evaporated till it reaches a specific gravity of 1·114 (15° Baumé), after which there is added to it a saturated solution of sulphate of soda. The acids exchange bases; sulphate of lime precipitates, and acetate of soda remains in solution. In some manufactures, instead of pursuing the above plan, the sulphate of soda is dissolved in the hot pyroligneous acid, which is afterwards saturated with chalk or lime. By this means no water need be employed to dissolve the sulphate, and accordingly the liquor is obtained in a concentrated form without evaporation. In both modes the sulphate of lime is allowed to settle, and the solution of acetate of soda is decanted. The residuum is set aside to be edulcorated, and the last waters are employed for washing fresh portions.

The acetate of soda which results from this double decomposition is afterwards evaporated till it attains to the density of 1·225 or 1·23, according to the season. This solution is poured into large crystallizing vessels, from which, at the end of 3 or 4 days, according to their capacity, the mother waters are decanted, and a first crystallization is obtained of rhomboidal prisms, which are highly colored and very bulky. Their facettes are finely polished, and their edges very sharp. The mother waters are submitted to successive evaporations and crystallizations till they refuse to crystallize, and they are then burnt to convert them into carbonate of soda.

To avoid guesswork proportions, which are always injurious, by the loss of time which they occasion, and by the bad results to which they often lead, we should determine experimentally, beforehand, the quantities absolutely necessary for the reciprocal decomposition, especially when we change the acid or the sulphate. But it may be remarked that, notwithstanding all the precautions we can take, there is always a notable quantity of sulphate of soda and acetic acid, which disappear totally in this decomposition. This arises from the circumstance that sulphate of soda and acetate of lime do not completely decompose each other, as I have ascertained by experiments on a very considerable scale; and thus a portion of each of them is always lost with the mother waters. It might be supposed that by calcining the acetate of lime we could completely destroy its empyreumatic oil; but, though I have made many experiments with this view, I never could abtain an acetate capable of affording a tolerable acid. Some manufacturers prefer to make the acetate of soda by direct saturation of the acid with the alkali, and think that the higher price of this substance is compensated by the economy of time and fuel which it produces.

The acetate of soda is easily purified by crystallizations and torrefaction; the latter process, when well conducted, freeing it completely from every particle of tar. This torrefaction, to which the name of fusion may be given, requires great care and dexterity. It is usually done in shallow cast iron boilers of a hemispherical shape. During all the time that the heat of about 500° Fahr. is applied, the fused mass must be diligently worked with rakes; an operation which continues about 24 hours for half a ton of materials. We must carefully avoid raising the temperature so high as to decompose the acetate, and be sure that the heat is equally distributed; for if any point of the mass enters into decomposition, it is propagated with such rapidity, as to be excessively difficult to stop its progress in destroying the whole. The heat should never be so great as to disengage any smoke, even when the whole acetate is liquefied. When there is no more frothing up, and the mass flows like oil, the operation is finished. It is now allowed to cool in a body, or it may be ladled out into moulds, which is preferable.

When the acetate is dissolved in water, the charcoaly matter proceeding from the decomposition of the tar must be separated by filtration, or by boiling up the liquor to the specific gravity 1·114, when the carbonaceous matter falls to the bottom. On evaporating the clear liquor, we obtain an acetate perfectly fine, which yields beautiful crystals on cooling. In this state of purity it is decomposed by sulphuric acid, in order to separate its acetic acid.

This last operation, however simple it appears, requires no little care and skill. The acetate of soda crystallized and ground is put into a copper, and the necessary quantity of sulphuric acid of 1·842 (about 35 per cent. of the salt) to decompose almost, but not all, the acetate, is poured on. The materials are left to act on each other; by degrees the acetic acid quits its combination, and swims upon the surface; the greater part of the resulting sulphate of soda falls in a pulverulent form, or in small granular crystals, to the bottom. Another portion remains dissolved in the liquid, which has a specific gravity of 1·08. By distillation we separate this remainder of the sulphate, and finally obtain acetic acid, having a specific gravity of 1·05, an agreeable taste and smell, though towards the end it becomes a little empyreumatic, and colored; for which reason, the last portions must be kept apart. The acid destined for table use ought to be distilled in an alembic whose capital and condensing worm are of silver; and to make it very fine, it may be afterwards infused over a little pure animal charcoal—the well-washed residuum of the Prussian-blue-works black.

An excise duty of 2*d.* is levied on every gallon of the above proof vinegar. Its strength is not, however, estimated directly by its specific gravity, but by the specific gravity which it assumes when saturated with quicklime. The decimal fraction of the specific gravity of the calcareous acetate is very nearly the double of that of the pure vinegar; or, 1·009 in vinegar becomes 1·018 in acetate of lime. The vinegar of malt contains so much mucilage or gluten, that when it has only the same acid strength as the above, it has a density of 1.0014, but it becomes only 1·023 when converted into acetate of lime: indeed, 0·005 of its density is due to mucilaginous matter. This fact shows the fallacy of trusting to the hydrometer for determining the strength of vinegars, which may be more or less loaded with vegetable gluten. The proper test of this, as of all other acids, is, the quantity of alkaline matter which a given weight or measure of it will saturate. For this purpose the bicarbonate of potash, commonly called, in the London shops, carbonate, may be employed very conveniently. As it is a very uniform substance, and its atomic weight, by the hydrogen radix, is 100·584, while the atomic weight of acetic acid, by the same radix, is 51·563, if we estimate 2 grains of the bicarbonate as equivalent to 1 of the real acid, we shall commit no appreciable error. Hence, a solution of the carbonate containing 200 grains in 100 measures, will form an acetimeter of the most perfect and convenient kind; for the measures of test liquid expended in saturating any measure,—for instance, an ounce or 1000 grains of acid,—will indicate the number of grains of real acetic acid in that quantity. Thus, 1000 grains of the above proof, would require 50 measures of the acetimetrical alkaline solution, showing that it contains 50 grains of real acetic acid in 1000, or 5 per cent.

It is common to add to purified wood vinegar, a little acetic ether, or caramelized (burnt) sugar to color it, also, in France, even wine, to flavor it. Its blanching effect upon red cabbage, which it has been employed to pickle, is owing to a little sulphurous acid. This may be removed by redistillation with peroxyde of manganese. Indeed, Stoltze professes to purify the pyroligneous acid solely by distilling it with peroxyde of manganese, and then digesting it with bruised wood charcoal; or by distilling it with a mixture of sulphuric acid and manganese. But much acid is lost in this case by the formation of acetate of that metal.

Birch and beech afford most pyroligneous acid, and pine the least. It is exclusively employed in the arts, for most purposes of which it need not be very highly purified. It is much used in calico printing, for preparing acetate of iron called Iron Liquor, and acetate of alumina, called Red Liquor; which see. It serves also to make sugar of lead; yet when it contains its usual quantity, after rectification of tarry matter, the acetate of lead will hardly crystallize, but forms cauliflower concretions. This evil may be remedied, I believe, by boiling the saline solution with a very little nitric acid, which causes the precipitation of a brown granular substance, and gives the liquor a reddish tinge. The solution being afterwards treated with bruised charcoal, becomes colorless, and furnishes regular crystals of acetate or sugar of lead.

Pyroligneous acid possesses, in a very eminent degree, anti-putrescent properties. Flesh steeped in it for a few hours may be afterwards dried in the air without corrupting; but it becomes hard, and somewhat leather-like: so that this mode of preservation does not answer well for butcher's meat. Fish are sometimes cured with it. See Pyro-acetic Spirit; Pyroxilic Ether; Pyroxolic Spirit; Pyroligneous Acid and Vinegar.

In 1838, 2,628,978 gallons of vinegar paid duty in England; in 1839, 2,989,665; and in 1840, 3,021,130; upon which the gross amount of duty was, respectively, 21,908*l.* 3*s.*; 24,448*l.* 17*s.* 6*d.*; and 25,978*l.* 12*s.* 9*d.*

In Scotland, in the same years, 15,626 gallons; 14,532; and 12,967; on which the duty charged was, respectively, 130*l.* 4*s.* 4*d.*; 121*l.* 2*s.*; and 111*l.* 19*s.* 7*d.*

In Ireland, in the same years, 48,158 gallons; 50,508; and 56,812; on which the duty charged was 401*l.* 6*s.* 4*s.*; 420*l.* 18*s.*; and 489*l.* 12*s.*

ACETIMETER. An apparatus for determining the strength of vinegar. See the preceding article for a description of my simple method of acetimetry.

ACETONE. The new chemical name of pyro-acetic spirit.

ACID OF ARSENIC. (*Acide arsenique*, Fr.; *Arseniksaure*, Germ.) See Arsenic.

ACIDS. A class of chemical substances characterized by the property of combining with and neutralizing the alkaline and other bases, and of thereby forming a peculiar class of bodies called salts. The acids which constitute objects of special manufacture for commercial purposes are the following:—acetic, arsenious, carbonic, chromic, citric, hydrocyanic, malic, muriatic, nitric, oxalic, phosphoric, sulphuric, tartaric, which see.

ACIDIMETER. See Alkalimeter.

ACROSPIRE. (*Plumule*, Fr.; *Blattkeim*, Germ.) That part of a germinating seed which botanists call the plumula, or plumes. See Beer and Malt.

ACTINISM. Some years ago, Mr. R. Hunt announced that he had discovered that, associated with the light and heat derived from the sun, there is another principle most active in producing changes in the organic and inorganic worlds, which he has called

Actinism, from the Greek for a ray of the sun. He has given the following striking evidences of the truth of his discovery, derived from the vegetable world. That the actinic principle was necessary to germination was shown by the fact, that seeds placed under the influence of the solar rays transmitted through yellow glass would not germinate, because yellow glass prevents the passage of the actinic principle. Accordingly, during spring the solar beam contained a larger amount of the actinic principle than at any other, because it was necessary at that season for the germination of seeds and the development of buds. In summer, again, there was a large proportion of the light-giving principle necessary to the formation of the woody portions of plants; and towards autumn the calorific heat giving or ripening principle of the solar rays increased. It resulted from these principles that the recent use in greenhouses of white German sheet glass was most objectionable. Under this kind of glass, plants were subject to an injurious solar influence which they had not suffered under the old crown glass. It became therefore necessary to discover some method to cut off those parathermic rays, which, passing through the white glass, scorched and browned particular portions of the leaves, without cutting off the other portions of the rays which were necessary to the growth of the plant. With this view Mr. Hunt has devised and applied at the Kew observatory a green glass stained with oxide of copper, which effectually excludes the injurious parathermic rays, while it admits the other solar rays necessary for the plant, as freely as ordinary white glass. In the manufacture of this green glass it was essential that no manganese should be used, as was the case in white glass. If manganese were used, the glass would after a while assume a pinkish hue, which would more freely admit the burning rays.

ADDITIONS. Such articles as are added to the fermenting wash of the distiller are distinguished by this trivial name.

ADIPOCIRE. Fr. (*Fettwachs*, Germ.) The fatty matter generated in dead bodies buried under peculiar circumstances. In 1786 and 1787, when the churchyard of the *Innocents*, at Paris, was cleaned out, and the bones transported to the catacombs, it was discovered that not a few of the *cadavres* were converted into a saponaceous white substance, more especially many of those which had been interred for fifteen years in one pit, to the amount of 1500, in coffins closely packed together. These bodies were flattened, in consequence of their mutual pressure; and, though they generally retained their shape, there was deposited round the bones of several a grayish white, somewhat soft, flexible substance. Fourcroy presented to the Academy of Sciences, in 1789, a comprehensive memoir upon this phenomenon, which appeared to prove that the fatty body was an ammoniacal soap, containing phosphate of lime; that the fat was similar to spermaceti, as it assumed on slow cooling a foliated crystalline structure; as also to wax, as, when rapidly cooled, it became granular: hence he called it *Adipocire*. Its melting point was 52·5° C. (126·5° Fahr.). He likewise compared this soap to the fat of gall-stones, and supposed it to be a natural product of the slow decomposition of all animal matter, except bones, nails, and hairs.

This substance was again examined by Chevreul in 1812, and was found by him to contain margaric acid, oleic acid, combined with a yellow coloring, odorous matter, besides ammonia, a little lime, potash, oxyde of iron, salts of lactic acid, an azotized substance; and was therefore considered as a combination of margaric and oleic acids, in variable proportions (whence arose its variable fusibility), but that it was not analogous with either spermaceti or cholesterine (gallstones). These fat acids are obviously generated by the reaction of the ammonia upon the margarine and oleine, though they eventually lose the greater part of that volatile alkali.

According to the views of both Gay Lussac and Chevreul, this *adipocire* proceeds solely from the pre-existing fat of the dead body, and not from the flesh, tendons, or cartilages, as had been previously imagined; which had led to some expensive and abortive attempts, upon the great scale of manufacture, to convert the dead bodies of cattle into adipocire, for the purposes of the candle-maker or soap-boiler, by exposing them for some time to the action of moisture.

Von Hartkol made experiments during 25 years upon this subject, from which he inferred, that there is no formation of adipocire in bodies buried in dry ground; that in moist earth the fat of the dead body does not increase, but changes into a fetid saponaceous substance, incapable of being worked into either soap or candles; that the dead bodies of *mammalia* immersed in running water, leave behind after 3 years a pure fat, which is more abundant from young than from old anmials; that the intestines afford more fat than the muscles; that from this fat, without any purification, candles may be made, as void of smell, as hard, and as white, as from bleached wax; that from cadavers immersed for 3 years in stagnant water, more fat is procured than from those in running water, but that it needs to be purified before it can be made into soap or candles.

The cause of the difference between Hartkol's and Chevreul's results cannot be assigned, as the latter has not published his promised remarks upon the subject. At any rate, dead animal matter can be worked up more profitably than in making artificial *adipocire.*

ADIT. The horizontal entrance of a mine. It is sometimes called the drift. See MINING and METALLURGY.

ADULTERATION. The debasing any product of manufacture, especially chemical, by the introduction of cheap materials. The art of ascertaining the genuineness of the several products will be taught under the specific objects of manufacture.

ÆTHER. See ETHER.

AFFINITY. The chemical term denoting the peculiar attractive force which produces the combination of dissimilar substances; such as of an alkali with an acid, or of sulphur with a metal. It is often called elective attraction, to distinguish it from corpuscular or cohesive attraction, by which particles of *like* kinds of matter are combined; and because it displays the power of selecting its preferable associates. Its full discussion belongs to chemistry.

AGARIC. A species of boletus or fungus, which grows in dunghills; with the salts of iron it affords a black dye. It is said to be convertible into a kind of china ink.

AGATE. A silicious mineral which is cut into seals and other forms for the coarser kinds of jewellery. See GEM.

AIR. See VENTILATION.

ALABASTER, is a stone usually white, and soft enough to be scratched by iron. There are two kinds of it: the gypseous, which is merely a natural semi-crystalline sulphate of lime; and the calcareous alabaster, which is a carbonate of lime. The oriental alabaster is always of the latter kind, and is most esteemed, because it is agreeably variegated with lively colors, and especially with zones of honey-yellow, yellow-brown, red, &c.; it is, moreover, susceptible of taking a marble polish.

The fineness of the grain of alabaster, the uniformity of its texture, the beauty of its polished surface, and its semi-transparency, are the qualities which render it valuable to the sculptor and to the manufacturer of ornamental toys.

The limestone alabaster is frequently found as a yellowish-white deposite in certain fountains. The most celebrated spring of this kind is that of the baths of San Filippo, in Tuscany. The water, almost boiling hot, runs over an enormous mass of stalactites, which it has formed, and holds the carbonate of lime in solution by means of sulphureted hydrogen (according to M. Alexandre Brongniard), which escapes by contact of the atmosphere. Advantage has been taken of this property to make *basso relievos* of considerable hardness, by placing moulds of sulphur very obliquely, or almost upright, in wooden tubs open at the bottom. These tubs are surmounted at the top with a large wooden cross. The water of the spring, after having deposited in an external conduit or cistern the coarser sediment, is made to flow upon this wooden cross, where it is scattered into little streamlets, and thence lets fall, upon the sulphur casts, a precipitate so much the finer the more nearly vertical the mould. From one to four months are required for this operation, according to the thickness of the deposited crust. By analogous processes, the artists have succeeded in moulding vases, figures of animals, and other objects, in relief, of every different form, which require only to be trimmed a little, and afterwards polished.

The common alabaster is composed of sulphuric acid and lime, though some kinds of it effervesce with acids, and therefore contain some carbonate of lime. This alabaster occurs in many different colors, and of very different degrees of hardness, but it is always softer than marble. It forms, usually, the lowest beds of the gypsum quarries. The sculptors prefer the hardest, the whitest, and those of a granular texture, like Carrara marble, and so like that they can only be distinguished by the hardness.

The alabaster is worked with the same tools as marble; and as it is many degrees softer, it is so much the more easily cut; but it is more difficult to polish, from its little solidity. After it has been fashioned into the desired form, and smoothed down with pumice stone, it is polished with a pap-like mixture of chalk, soap, and milk; and, last of all, finished by friction with flannel. It is apt to acquire a yellowish tinge.

Besides the harder kinds, employed for the sculpture of large figures, there is a softer alabaster, pure white and semi-transparent, from which small ornamental objects are made, such as boxes, vases, lamps, stands of time-pieces, &c. This branch of business is much prosecuted in Florence, Leghorn, Milan, &c., and employs a great many turning lathes. Of all the alabasters, the Florentine merits the preference, on account of its beauty and uniformity, so that it may be fashioned into figures of considerable size: for which purpose there are large work-shops where it is cut with steel saws into blocks and masses of various shapes. Other sorts of gypsum, such as that of Salzburg and Austria, contain sand veins, and hard nodules, and require to be quarried by cleaving and blasting operations which are apt to crack it, and unfit it for all delicate objects of sculpture. It is besides of a gray shade, and often stained with darker colors.

The alabaster best adapted for the fine arts is pretty white when newly broken, and becomes whiter on the surface by drying. It may be easily cut with the knife or chisel, and formed into many pleasing shapes by suitable steel tools. It is worked either by the hand alone, or with the aid of a turning lathe. The turning tools should not be too thin, or sharp-edged; but such as are employed for ivory and brass are most suitable for alabaster, and are chiefly used to shave and to scratch the surface. The objects which cannot be turned may be fashioned by the rasping tools, or with minute files, such as variegated foliage. Fine chisels and graving tools are also used for the better pieces of statuary.

For polishing such works, a peculiar process is required; pumice stone, in fine powder, serves to smooth down the surfaces very well, but it soils the whiteness of the alabaster. To take away the unevenness and roughness, dried shave-grass (*equisetum* answers best. Frictions with this plant and water polish down the asperities left by the chisel: the fine streaks left by the grass may be removed by rubbing the pieces with slaked lime, finely pulverized and sifted, made into a paste or putty with water. The polish and satin-lustre of the surface are communicated by friction, first with soap-water and lime, and finally with powdered and elutriated talc or French chalk.

Such articles as consist of several pieces are joined by a cement composed of quicklime and white of egg, or of well-calcined and well-sifted Paris plaster, mixed with the least possible quantity of water.

Alabaster objects are liable to become yellow by keeping, and are especially injured by smoke, dust, &c. They may be in some measure restored by washing with soap and water, then with clear water, and again polished with shave-grass. Grease-spots may be removed either by rubbing with talc powder, or with oil of turpentine.

The surface of alabaster may be etched by covering over the parts that are not to be touched with a solution of wax in oil of turpentine, thickened with white lead, and immersing the articles in pure water after the varnish has set. The action of the water is continued from 20 to 50 hours, more or less, according to the depth to which the etching is to be cut. After removing the varnish with oil of turpentine, the etched places, which are necessarily deprived of their polish, should be rubbed with a brush dipped in finely-powdered gypsum, which gives a kind of opacity, contrasting well with the rest of the surface.

Alabaster may be stained either with metallic solutions, with spirituous tinctures of dyeing plants, or with colored oils, in the same way as marbles.

This substance has been hardened, it is said, by exposing it to the heat of a baker's oven for 10 or 20 hours, after taking it out of the quarry, and giving it the figure, roughly, which it is intended to have. After this exposure, it must be dipped for two minutes in running water; when it is cold, it must be dipped a second time for the same period. On being exposed to the air for a few days, alabaster so treated acquires a marble-like hardness. I doubt the truth of this last statement. I believe a much better means of induration would be by soaking it in solution of alum. Alabaster is by the mineralogist considered as hydrous gypsum; and consists of one atom of sulphuric acid, one atom of lime, and two atoms of water.

ALBATA. A white metal like silver; see COPPER, of which it is an alloy with nickel and zinc.

ALBUM GRÆCUM. The white dung of dogs, sometimes used to soften leather in the process of dressing it after the depilatory action of lime. It is essentially phosphate of lime and mucus.

ALBUMINE, an animal product, like white of egg, which is diffused through the whole body, and is on account of the multifarious uses which it subserves in the vital economy called Proteine. It consists of carbon 55·0; hydrogen 7·07; oxygen 22·0; azote 15·92.

ALCARAZZAS. A species of porous earthenware, made in Spain, for cooling liquors. Alcarazzas are made of a sandy marl, made up into a dough, with a solution of salt, and very little fired. M. Fourmy has mounted a factory of them in Paris under the Greek title of *Hygroceramen.*

ALCOHOL. The well-known intoxicating liquor procured by distillation from various vegetable juices, and infusions of a saccharine nature, which have undergone the vinous fermentation. Common alcohol, or proof spirit, as it is called, contains about one-half its weight of water. It may be concentrated till its specific gravity becomes so low as 0·825, by simple redistillation at a steam or water-bath heat; but to make it stronger, we must mix with it, in the still or retort, dry carbonate of potash, chloride of calcium, dry lime, or some other substances strongly attractive of water, and then it may be obtained of a specific gravity so low as 0·791 at 16° Reaumur (68° Fahr.), water being 1·000

At 0·825, it contains, still, 11 per cent. of water; and in this state it is as volatile as absolute alcohol, on account of the inferior density of the aqueous vapor, compared to the alcoholic. Indeed, according to Yelin and Fuchs, the boiling point of anhydrous alcohol is higher than of that which contains 2 or 3 per cent. of water; hence, in the distillation of alcohol of 94 per cent., the first portions that come over are more aqueous than the following. Absolute alcohol has its boiling point at 168½° Fahr.; but when it holds more than 6 per cent. of water, the first portions that come over are richest in alcohol, and the temperature of the boiling point, or of the spirituous vapor, is always higher the longer the distillation continues. According to Gröning's researches, the following temperatures of the alcoholic vapors correspond to the accompanying contents of alcohol in per centage of volume, which are disengaged in the boiling of the spirituous liquid.

Temperature.	Alcoholic content of the vapor.	Alcoholic content of the boiling liquid.	Temperature.	Alcoholic content of the vapor.	Alcoholic content of the boiling liquid.
Fahr. 170·0	93	92	Fahr. 189·8	71	20
171·8	92	90	192·0	68	18
172	91	85	164	66	15
172·8	90½	80	196·4	61	12
174	90	70	198·6	55	10
174·6	89	70	201	50	7
176	87	65	203	42	5
178·3	85	50	205·4	36	3
180·8	82	40	207·7	28	2
183	80	35	210	13	1
185	78	30	212	0	0
187·4	76	25			

Gröning undertook this investigation in order to employ the thermometer as an alcohol-meter in the distillation of spirits: for which purpose he thrust the bulb of the thermometer through a cork, inserted into a tube fixed in the capital of the still. The state of the barometer ought also to be considered in making comparative experiments of this kind. Since, by this method, the alcoholic content may be compared with the temperature of the vapor that passes over at any time, so, also, the contents of the whole distillation may be found approximately; and the method serves as a convenient means of making continual observations on the progress of the distillation.

The Abbé Vidal of Toulon constructed a few years ago an instrument which he termed the *Ebullition Alcoolmètre,* for estimating the strength of alcohol from the temperature of its boiling point. It is an awkward apparatus, consisting of a large cylindrical glass bulb, like that of a wheel barometer, containing mercury, and a floating glass bead, with a thread attached; the other end of which passed over a little pulley, and was terminated by a counterweight. Concentric with this pulley a graduated flat ring of brass was fixed, on which an index traversed with the pulley, as it was moved by the thread in its ascent by the mercury in its expansions by the heat of the alcohol, placed in a little cylinder into which the bulb was plunged. This cylinder was subjected to the flame of a little spirit lamp. I found the instrument, as thus made in France, difficult to manage, easily deranged by a loss of a drop of the mercury, and difficult to repair. I therefore substituted a simple thermometer, with a very narrow bore from 212° to 184° Fahr. and consequently a long range of scale between these two points. The scale was divided as follows:

Temp. Fahr.	Sp. Gr.	Temp. Fahr.	Sp. Gr.
178·60	0·920 P.	185·6	0·9665 50 U. P.
179·75	0·9821 10 U. P.	189·0	0·9729 60
180·4	0·9420 20	191·8	0·9786 70
182·00	0·9516 30	196·4	0·9850 80
183·40	0·960 40	202·0	0·992 90

The above table is the mean of a great many experiments. P. means proof spirits of the British excise standard; U. P. denotes under proof.—*In the Pharmaceutical Journal,* vol. 7. p. 166., there is a detailed account, with engravings, of the two instruments.

The first of the following two tables of the boiling points of alcohol of different strengths may be compared with my short one given above.

Gröning.		Yelin.	
Alcohol. in 100.	Boiling Point.	Alcohol in 100.	Boiling Point.
5	96·3° C.	94	76·97° C.
10	92·9	95	76·99
15	91·0	96	76·92
20	89·1	97	76·85
25	87·5	98	76·85
30	86·2	99	76·90
35	85·0	100	77·02
40	84·1		
45	83·4		
50	83·1		
55	82·2		
60	81·9		
65	81·5		
70	80·9		
75	80·3		
80	79·7		
85	79·4		
90	79·0		
95	78·4		

Proof spirit of sp. gr. 0·92 at 60° Fahr. consists of absolute alcohol of gravity 0·794, and of distilled water very near equal weights; but in volumes, of 126 of alcohol and 100 of water; therefore 100 measures of such spirits contain 55·75 of the alcohol $=\left(\frac{126}{226}\right)$. By the table of Gay Lussac, spirits that 'contain 55·75 of absolute alcohol have a specific gravity of 0·9218 instead of 0·9200; while spirits of 0·9200, according to Gay Lussac, contain 56·66 in 100 by volume. By the table of Tralles, spirits of 0·825 contain 92·43 of the said alcohol; and hence $\frac{100+56{\cdot}66}{92{\cdot}43}=60{\cdot}6\frac{0}{0}$ of Gilpin's alcohol by Gay Lussac; whereas by Gilpin's table, spirits of 0·9200 contain 100 of alcohol of 0·825 + 81·2 of water by weight: and $\frac{100}{0{\cdot}825}=121{\cdot}2121$ by volume. Again, 121·2121 + 81·2 = 202·2121; 121·2121 divided by 202·2121 gives a quotient of 59·88 as the alcohol of 0·825 in the 100 by volume. Now as 60·6 by Gay Lussac's table exceeds 59·88 by 0·72, there must be an error; most probably on the side of the French chemist.

The temperature, corresponding to a certain per centage of alcohol in vapor, suggests the employment of a convenient method for obtaining, at one process, a spirit as free from water as it can be made by mere distillation. We place over the top of the capital a water-bath, and lead up through it a spiral pipe from the still, which there passes obliquely downwards, and proceeds to the refrigeratory. If this bath be maintained, by a constant influx of cold water, at a certain temperature, only the alcoholic vapor corresponding to that temperature will pass over, and the rest will be recondensed and returned into the still. If we keep the temperature of the water at 174°, for example, the spirituous vapor which passes over will contain 90 per cent. of absolute alcohol, according to the preceding table. The skilful use of this principle constitutes the main improvement in modern distilleries. See Distillation and Still.

Another method for concentrating alcohol is that discovered by Sömmering, founded upon the property of ox bladders to allow water to pass through and evaporate out of them, but not to permit alcohol to transpire, or only in a slight degree. Hence, if an ox's bladder is filled with spirit of wine, well tied at the mouth, and suspended in a warm place, the water will continually exhale, and the alcohol will become nearly anhydrous; for in this way alcohol of 97 or 98 per cent. may be obtained.

According to Sömmering, we should take for this purpose the bladder of an ox or a calf, soak it for some time in water, then inflate it and free it from the fat and the attached vessels; which is to be also done to the other surface, by turning it inside out. After it is again inflated and dried, we must smear over the outer side twice, and the inner side four times, with a solution of isinglass, by which its texture is made closer, and the concentration of the alcohol goes on better. A bladder so prepared may serve more than a hundred times. It must be charged with the spirits to be concentrated, leaving a small space vacant, it is then to be tightly bound at the mouth, and suspended in a warm situation, at a temperature of 122° Fahr., over a sand-bath, or in the neighborhood of an oven. The surface of the bladder remains moist with the water as long as the sp. gr. of the contained spirit is greater than 0.952. Weak spirit loses its water quicker than strong; but in from 6 to 12 hours the alcohol may be concentrated when a suitable heat is employed. This economical method is particularly applicable in obtaining alcohol for the preparation of varnishes. When the alcohol is to serve for other purposes it must be freed, by distillation, from certain matters dissolved out of the bladder. Alcohol may likewise be strengthened, as Sömmering has ascertained, when the vessel that contains the spirit is bound over with a bladder which does not come into contact with the liquid. Thus, too, all other liquors containing alcohol and water, as wine, cider, &c., may be made more spirituous.

To procure absolute alcohol, we must take chloride of calcium recently fused, reduce it to a coarse powder, and mix it with its own weight of spirits of wine, of sp. gr. 0.833, in a bottle, which is to be well stoppered, and to be agitated till the salt is dissolved. The clear solution is to be poured into a retort, and half of the volume of the alcohol employed, or so much as has the sp. gr. 0.791 at 78° Fahr., is to be distilled off, drop by drop, at a gentle heat. Quicklime has also been employed for the same purpose, but it is less powerful and convenient. Alcohol, nearly free from water, may be obtained without distillation, by adding dry carbonate of potash to a spirit of wine, of sp. gr. 0·825. The water combines with the potash, and falls to the bottom in a dense liquid, while the pure spirit floats on the surface. This contains, however, a little alkali, which can be separated only by distillation.

Anhydrous alcohol is composed by weight of 52·18 carbon, 13·04 hydrogen, and 34·78 of oxygen. It has for its symbol $C_4H_6O_2 = C_4H_4, H_2O_2$; or one atom of ether + one atom of water; it is therefore a hydrate of ether. It has a very powerful attraction for water, and absorbs it from the atmosphere; therefore it must be kept in well-closed vessels. It also robs vegetable and animal bodies of their moisture; and hence common alcohol is employed for preserving anatomical preparations. Alcohol is a solvent for many substances: resins, essential oils, camphor, are abundantly dissolved by it, forming varnishes, perfumed spirits, &c. The solution of a resin or essential oil in alcohol becomes milky on the addition of water, which, by its attraction for alcohol, separates these substances. Several salts, especially the deliquescent, are dissolved by it, and some of them give a color to its flame; thus the solutions of the salts of strontia in alcohol burn with a crimson flame; those of copper and borax green, lime reddish, and baryta yellow.

When water is mixed with alcohol, heat and a condensation of volume are the result; these effects being greatest with 54 per cent. of alcohol and 46 of water, and thence decreasing with a greater proportion of water. For alcohol which contains 90 per cent. of water, this condensation amounts to 1·94 per cent. of the volume; for 80 per cent., 2·87; for 70 per cent., 3·44; for 60 per cent., 3·73; for 40 per cent., 3·44; for 30 per cent., 2·72; for 20 per cent., 1·72; for 10 per cent., 0·72. Hence, to estimate the quantity of alcohol in any spirit, it is necessary that the specific gravity be ascertained for each determinate proportion of alcohol and water that are mixed together. When this is done, we may, by means of an aerometer constructed for liquids lighter than water, determine the strength of the spirit, either by a scale of specific gravities or by an arbitrary graduation corresponding to certain commercial objects, and thus we may determine the percentage of alcohol in whisky or brandy of any strength or purity. An areometer intended for this use has been called an alcoholmeter, in particular when the scale of it is so graduated that instead of the specific gravity, it indicates immediately the percentage of anhydrous alcohol in a given weight or volume of the liquid. The scale graduated according to the percentage of pure alcohol by weight, constitutes the alcoholmeter of Richter; and that by the percentage in volume, the alcoholmeter of Tralles and Gay Lussac.

As liquors are sold in general by the measure, not by the weight, it is convenient, therefore, to know the alcoholic content of the mixtures in the percentage by volume Tralles has constructed new tables upon the principles of those of Gilpin, in which the proportion is given by volume, and anhydrous alcohol is assumed for the basis which at 60° Fahr., has a specific gravity of 0·7939 compared with water at its maximum density, or a specific gravity of 0·7946 compared with water of the temperature of 60° Fahr. Gilpin's alcohol of 0·825 contains 92·6 per cent. by volume of anhydrous alcohol.

According to the experiments of Tralles alcohol contracts between—26° C. and + 37 C. with tolerable uniformity; for each degree the contraction is 0·00846 of the volume of the alcohol. In the following table its contractions are reckoned downwards from the boiling point by Gay Lussac.

Temp.	Volume.	Temp.	Volume.	Temp.	Volume.
78°·4	1000·	48°·4	965·3	23°·4	938·6
73°·4	994·4	43°·4	960·0	18°·4	934·0
68°·4	988·6	38°·4	954·4	13°·4	929·3
63°·4	982·5	33°·4	948·9	8°·4	924·5
58°·4	975·7	28°·4	943·6	3°·4	919·0
53°·4	970·9				

Spirituous vapor passed through an ignited tube of glass or porcelain is converted into carbonic oxide, water, hydrogen, carburetted hydrogen, olefiant gas, naphthaline, empyreumatic oil, and carbon; according to the degree of heat and nature of the tube these products vary. Anhydrous alcohol is a non-conductor of electricity, but is decomposed by a powerful voltaic battery. Alcohol burns in the air with a blue flame into carbonic acid and water; the water being heavier than the spirit, because 46 parts of alcohol contain 6 of hydrogen, which form 54 of water. In oxygen the combustion is accompanied with great heat, and this flame, directed through a small tube, powerfully ignites bodies exposed to it.

If we moisten sand in a capsule with absolute alcohol, and cover it with previously heated nickel powder, protoxide of nickel, cobalt powder, protoxide of cobalt, protoxide of uranium, oxide of tin (these six bodies being procured by ignition of their oxalates in a crucible), or finely powdered manganese peroxide, combustion takes place, and continues as long as the spirituous vapor lasts.

The following table exhibits the per centage of anhydrous alcohol by volume, at a temperature of 60° Fahr., in correspondence with the specific gravities of the spirits, water being considered at 60° Fahr. to have a specific gravity of 0·9991.

Alcoholmetrical Table of Tralles.

Alcohol in 100 measures of spirit.	Specific gravity at 60° Fahr.	Difference of the sp. gr.	Alcohol in 100 measures of spirit.	Specific gravity at 60° Fahr.	Difference of the sp. gr.
0	9991		51	9315	20
1	9976	15	52	9295	20
2	9961	15	53	9275	20
3	9947	14	54	9254	21
4	9933	14	55	9234	20
5	9919	14	56	9213	21
6	9906	13	57	9192	21
7	9893	13	58	9170	22
8	9881	12	59	9148	22
9	9869	12	60	9126	22
10	9857	12	61	9104	22
11	9845	12	62	9082	22
12	9834	11	63	9059	23
13	9823	11	64	9036	23
14	9812	11	65	9013	23
15	9802	10	66	8989	24
16	9791	11	67	8965	24
17	9781	10	68	8941	24
18	9771	10	69	8917	24
19	9761	10	70	8892	25
20	9751	10	71	8867	25
21	9741	10	72	8842	25
22	9731	10	73	8817	25
23	9720	11	74	8791	26
24	9710	10	75	8765	26
25	9700	10	76	8739	26
26	9689	11	77	8712	27
27	9679	10	78	8685	27
28	9668	11	79	8658	27
29	9657	11	80	8631	27
30	9646	11	81	8603	28
31	9634	12	82	8575	28
32	9622	12	83	8547	28
33	9609	13	84	8518	29

Alcoholmetrical Table of Tralles (*continued*).

Alcohol in 100 measures of spirit.	Specific gravity at 60° Fahr.	Difference of the sp. gr.	Alcohol in 100 measures of spirit	Specific gravity at 60° Fahr.	Difference of the sp gr.
34	9596	13	85	8488	30
35	9583	13	86	8458	30
36	9570	13	87	8428	30
37	9556	14	88	8397	31
38	9541	15	89	8365	32
39	9526	15	90	8332	33
40	9510	16	91	8299	33
41	9494	16	92	8265	34
42	9478	16	93	8230	35
43	9461	17	94	8194	36
44	9444	17	95	8157	37
45	9427	17	96	8118	39
46	9409	18	97	8077	41
47	9391	18	98	8034	43
48	9373	18	99	7988	46
49	9354	19	100	7939	49
50	9335	19			

Remarks on the preceding Table of Alcohol.

The third column of this table exhibits the differences of the specific gravities, which give the denominator of the fraction for such densities as are not found sufficiently near in the table; and the difference of their numerators is the next greatest to the density found in the table. For example: if the specific gravity of the liquor found for 60° Fahr. = 9605 (the per centage will be between 33 and 34), the difference from 9609 (which is the next greatest number in the table) = 4, and the fraction is $\frac{4}{13}$· therefore the true per centage is 33$\frac{4}{13}$. From the construction of this table the per centage of alcohol by weight may also be found. For instance: we multiply the number representing the *volumes* of alcohol (given in the table for any determinate specific gravity of the mixture) by the specific gravity of the pure alcohol, that is, by 7939, and the product is the number of pounds of alcohol in so many pounds as the specific gravity multiplied by 100 gives. Thus, in the mixture of 9510 specific gravity, there are 40 measures of alcohol; hence there are also in 95,100 pounds of this spirit 7939 + 40 = 31·756 pounds of alcohol; and in 100 pounds of the spirits of 0·9510 specific gravity, 33·39 pounds of alcohol are contained.

As the preceding table gives the true alcoholic content when the portion of spirit under trial has the normal temperature of 60° Fahr., the following table gives the per centage of alcohol for the specific gravities corresponding to the accompanying temperatures.

For example: if we have a spirituous liquor at 80° Fahr., whose specific gravity is 0·9342, the alcohol present is 45 per cent. of the volume, or that specific gravity at that temperature is equal to the specific gravity 0·9427 at the normal temperature of 60° Fahr. This table may also be employed for every degree of the thermometer and

Alcohol per cent.	Temperature.						Alcohol per cent.	Temperature.					
	30° F.	35° F.	40° F.	45° F.	50° F.	55° F.		60° F.	65° F.	70° F.	75° F.	80° F.	85° F.
0	9994	9997	9997	9998	9997	9994	0	9991	9987	9991	9976	9970	9962
5	9924	9926	9926	9926	9925	9922	5	9919	9915	9909	9903	9897	9889
10	9868	9869	9868	9867	9865	9861	10	9857	9852	9845	9839	9831	9823
15	9823	9822	9820	9817	9813	9807	15	9802	9796	9788	9779	9771	9761
20	9786	9782	9777	9772	9766	9759	20	9751	9743	9733	9722	9711	9700
25	9753	9746	9738	9729	9720	9709	25	9700	9690	9678	9665	9652	9638
30	9717	9707	9695	9684	9672	9659	30	9646	9632	9618	9603	9588	9572
35	9671	9658	9644	9629	9614	9599	35	9583	9566	9549	9532	9514	9495
40	9615	9598	9581	9563	9546	9528	40	9510	9491	9472	9452	9433	9412
45	9544	9525	9506	9486	9467	9447	45	9427	9406	9385	9364	9342	9320
50	9460	9440	9420	9399	9378	9356	50	9335	9313	9290	9267	9244	9221
55	9368	9347	9325	9302	9279	9256	55	9234	9211	9187	9163	9139	9114
60	9267	9245	9222	9198	9174	9150	60	9126	9102	9076	9051	9026	9000
65	9162	9138	9113	9088	9063	9038	65	9013	8988	8962	8936	8909	8882
70	9046	9021	8996	8970	8944	8917	70	8892	8866	8839	8812	8784	8756
75	8925	8899	8873	8847	8820	8792	75	8765	8738	8710	8681	8652	8622
80	8798	8771	8744	8716	8688	8659	80	8631	8602	8573	8544	8514	8483
85	8663	8635	8606	8577	8547	8517	85	8488	8458	8427	8396	8365	8333
90	8517	8486	8455	8425	8395	8363	90	8332	8300	8268	8236	8204	8171

every per centage, so as to save computation for the intervals. It is evident from inspection that a difference of 5° Fahr. in the temperature changes the specific gravity of the liquor by a difference nearly equal to 1 volume per cent. of alcohol; thus at 35° and 85° Fahr. the very same specific gravity of the liquor shows nearly 10 volumes per cent. of alcohol more or less; the same, for example, at 60 and 40 per cent.

The importance of extreme accuracy in determining the density of alcoholic mixtures in the United Kingdom, on account of the great revenue derived from them to the State, and their consequent high price in commerce, induced the Lords of the Treasury a few years ago to request the Royal Society to examine the construction and mode of applying the instrument now in use for ascertaining and charging the duty on spirits. This instrument, which is known and described in the law as Sikes's hydrometer, possesses, in many respects, decided advantages over those formerly in use. The committee of the Royal Society state, that a definite mixture of alcohol and water is as invariable in its value as absolute alcohol can be; and can be more readily, and with equal accuracy, identified by that only quality or condition to which recourse can be had in practice, namely, specific gravity. The committee further proposed, that the standard spirit be that which, consisting of alcohol and water alone, shall have a specific gravity of 0·92 at the temperature of 62° Fahr., water being unity at the same temperature; or, in other words, that it shall at 62° weigh $\frac{92}{100}$ or $\frac{23}{25}$ of an equal bulk of water at the same temperature.

This standard is rather weaker than the old proof, which was $\frac{12}{13}$, or 0·923; or in the proportion of nearly 1·1 gallon of the present proof spirit per cent. The proposed standard will contain nearly one half by weight of absolute alcohol. The hydrometer ought to be so graduated as to give the indication of strength; not upon an arbitrary scale, but in terms of specific gravity at the temperature of 62°.

The committee recommend the construction of an equation table, which shall indicate the same strength of spirit at every temperature. Thus in standard spirit at 62° the hydrometer would indicate 920, which in this table would give proof spirit. If that same spirit were cooled to 40°, the hydrometer would indicate some higher number; but which, being combined in the table with the temperature as indicated by the thermometer, should still give proof or standard spirit as the result.

It is considered advisable, in this and the other tables, not to express the quality of the spirit by any number over or under proof, but to indicate at once the number of gallons of standard spirit contained in, or equivalent to, 100 gallons of the spirit under examination. Thus, instead of saying 23 over proof, it is proposed to insert 123; and in place of 35·4 under proof, to insert its difference to 100, or 64·6.

It has been considered expedient to recommend a second table to be constructed, so as to show the bulk of spirit of any strength at any temperature, relative to a standard bulk of 100 gallons at 62°. In this table a spirit which had diminished in volume, at any given temperature, 0·7 per cent., for example, would be expressed by 99·3; and a spirit which had increased at any given temperature 0·7 per cent., by 100·7.

When a sample of spirit, therefore, has been examined by the hydrometer and thermometer, these tables will give first the proportion of standard spirit at the observed temperature, and next the change of bulk of such spirit from what it would be at the standard temperature. Thus, at the temperature of 51°, and with an indication (sp. gr.) of 8240, 100 gallons of the spirit under examination would be shown by the first table to be equal to 164·8 gallons of standard spirit of that temperature; and by the second table it would appear that 99·3 gallons of the same spirit would become 100 at 62°, or in reality contain the 164·8 gallons of spirit in that state only in which it is to be taxed.

But as it is considered that neither of these tables can alone be used for charging the duty (for neither can express the actual quantity of spirit of a specific gravity of 0·92 at 62° in 100 gallons of stronger or weaker spirit at temperatures above or below 62°), it is considered essential to have a third table, combining the two former, and expressing this relation directly, so that upon mere inspection it shall indicate the proportion of standard spirit in 100 gallons of that under examination in its then present state. In this table the quantities should be set down in the actual number of gallons of standard spirit at 62°, equivalent to 100 of the spirit under examination; and the column of quantities may be expressed by the term *value*, as it in reality expresses the proportion of the only valuable substance present. As this will be the only table absolutely necessary to be used with the instrument for the purposes of the excise, it may, perhaps, be thought unnecessary to print the former two.

The following specimen table has been given by the committee:—

Temperature 45°.			Temperature 75°.		
Indication.*	Strength.	Value.	Indication.	Strength.	Value.
9074	114·5		8941	114·5	
7	114·3		4	114·3	
9	114·2		5	114·2	
81	114·0		8	114·0	
3	113·9		9	113·9	
5	113·7		52	113·7	
6	113·6		3	113·6	
9	113·4		6	113·4	
90	113·3		7	113·3	
3	113·1		9	113·1	

The mixture of alcohol and water, taken as spirit in Mr. Gilpin's tables, is that of which the specific gravity is 0·825 at 60° Fahr., water being unity at the same temperature. The specific gravity of water at 60° being 1000, at 62° it is 99,981. Hence, in order to compare the specific gravities given by Mr. Gilpin with those which would result when the specific gravity of water at 62° is taken at unity, all the former numbers must be divided by 99,981.

Table of the Specific Gravities of different Mixtures, by Weight, of Alcohol and Water, at different Temperatures; constructed by Mr. Gilpin, for the use of the British Revenue on Spirits.

Temperature, Fahr.	Pure Alcohol	100 Alcohol 5 Water.	100 Alcohol 10 Water.	100 Alcohol 15 Water.	100 Alcohol 20 Water.	100 Alcohol 25 Water.	100 Alcohol 30 Water.	100 Alcohol 35 Water.	100 Alcohol 40 Water.	100 Alcohol 45 Water.	100 Alcohol 50 Water.
Deg. 30	0·83896	0·84995	0·85957	0·86825	0·87585	0·88282	0·88921	0·89511	0·90054	0·90558	0·91023
35	·83672	·84769	·85729	·86587	·87357	·88059	·88701	·89294	·89839	·90345	·90811
40	·83445	·84539	·85507	·86361	·87184	·87838	·88481	·89073	·89617	·90127	·90596
45	·83214	·84310	·85277	·86131	·86905	·87613	·88255	·88849	·89396	·89909	·90380
50	·82977	·84076	·85042	·85902	·86676	·87384	·88030	·88626	·89174	·89684	·90160
55	·82736	·83834	·84802	·85664	·86441	·87150	·87796	·88393	·88945	·89458	·89933
60	·82500	·83599	·84568	·85430	·86208	·86918	·87569	·88169	·88720	·89232	·89707
65	·82262	·83362	·84334	·85193	·85976	·86686	·87337	·87938	·88490	·89006	·89479
70	·82023	·83124	·84092	·84951	·85736	·86451	·87105	·87705	·88254	·88773	·89252
75	·81780	·82878	·83851	·84710	·85496	·86212	·86864	·87466	·88018	·88538	·89018
80	·81530	·82631	·83603	·84467	·85248	·85966	·86622	·87228	·87776	·88301	·88781
85	·81291	·82396	·83371	·84243	·85036	·85757	·86411	·87021	·87590	·88120	·88609
90	·81044	·82150	·83126	·84001	·84797	·85518	·86172	·86787	87360	87889	·88376
95	·80794	·81900	·82877	·83753	·84550	·85272	·85928	·86542	·87114	·87654	·88146
100	·80548	·81657	·82639	·83513	·84038	·85031	·85688	·86302	·86879	·87421	·87915

Temperature, Fahr.	100 Alcohol 55 Water.	100 Alcohol 60 Water.	100 Alcohol 65 Water.	100 Alcohol 70 Water.	100 Alcohol 75 Water.	100 Alcohol 80 Water.	100 Alcohol 85 Water.	100 Alcohol 90 Water.	100 Alcohol 95 Water.	100 Alcohol 100 Water
Deg. 30	0·91449	0·91847	0·92217	0·92563	0·92889	0·93191	0·93474	0·93741	0·93991	0·94222
35	·91241	·91640	·92009	·92355	·92680	·92986	·93274	·93541	·93790	·94025
40	·91026	·91428	·91799	·92151	·92476	·92783	·93072	·93341	·93592	·93827
45	·90812	91211	·91584	·91937	·92264	·92570	·92859	·93131	·93382	·93621
50	·90596	·90997	·91370	·91723	·92051	·92358	·92647	·92919	·93177	·93419
55	·90367	·90768	·91144	·91502	·91837	·92145	·92436	·92707	·92963	·93208
60	·90144	·90549	90927	·91287	·91622	·91933	·92225	·92499	·92758	·93002
65	·89920	·90328	·90707	·91066	·91400	·91715	·92010	·92283	·92546	·92794
70	·89695	·90104	·90484	·90847	·91181	·91493	·91793	·92069	·92333	·92580
75	·89464	·89872	·90252	·90617	·90952	·91270	·91569	·91849	·92111	·92364
80	·89225	·89639	·90021	·90385	·90723	·91046	·91340	·91622	·91891	·92142
85	·89043	·89460	·89843	·90209	·90558	·90882	·91186	·91465	·91729	·91969
90	88817	·89230	·89617	·89988	·90342	·90688	·90967	·91248	·91511	·91751
95	·88588	·89003	·89390	·89763	·90119	·90443	·90747	·91029	·91290	91531
100	·83571	88769	·89158	·89536	·89889	·90215	·90522	·90805	·91066	91310

* By specific gravity.

Table of the Specific Gravities of different Mixtures, &c. (*continued*).

Temperature, Fahr.	95 Alcohol 100 Water.	90 Alcohol 100 Water.	85 Alcohol 100 Water.	80 Alcohol 100 Water.	75 Alcohol 100 Water.	70 Alcohol 100 Water.	65 Alcohol 100 Water.	60 Alcohol 100 Water.	55 Alcohol 100 Water.	50 Alcohol 100 Water.
Deg.										
30	0·94447	0·94675	0·94920	0·95173	0·95429	0·95681	0·95944	0·96209	0·96470	0·96719
35	·94249	·94484	·94734	·94988	·95246	·95502	·95772	·96048	·96315	·96579
40	·94058	·94295	·94547	·94802	·95060	·95328	·95602	·95879	·96159	96434
45	·93860	·94096	·94348	·94605	·94871	·95143	·95423	·95703	·95993	96280
50	·93658	·93897	·94149	·94414	·94683	·94958	·95243	·95534	·95831	·96126
55	·93452	·93696	·93948	·94213	·94486	·94767	·95057	·95357	·95662	·95966
60	·93247	·93493	·93749	·94018	·94296	·94579	·94876	·95181	95493	·95804
65	·93040	·93285	·93546	·93822	·94099	·94388	·94669	·95000	·95318	·95635
70	·92828	·93076	·93337	·93616	·93898	·94193	·94500	·94813	·95139	·95469
75	·92613	·92865	·93132	·93413	·93695	·93989	·94301	·94623	·94957	·95292
80	·92393	·92646	92917	·93201	·93488	·93785	·94102	·94431	·94768	·95111

Temperature, Fahr.	45 Alcohol 100 Water.	40 Alcohol 100 Water.	35 Alcohol 100 Water.	30 Alcohol 100 Water.	25 Alcohol 100 Water.	20 Alcohol 100 Water	15 Alcohol 100 Water.	10 Alcohol 100 Water.	5 Alcohol 100 Water.
Degrees.									
30	0·96967	0·97200	0·97418	0·97635	0·97860	0·98108	0·98412	0·98804	0·99334
35	·96840	·97086	·97319	·97556	·97801	·98076	·98397	·98804	·99344
40	·96706	·96967	·97220	·97472	·97737	·98033	·98373	·98795	·99345
45	·96563	·96840	·97110	·97384	·97666	·97980	·98338	·98774	·99338
50	·96420	·96708	·96995	·97284	·97589	·97920	·98293	·98745	·99316
55	·96272	·96575	·96877	·97181	·97500	·97847	·98239	·98702	·99284
60	·96122	·96437	·96752	·97074	·97410	·97771	·98176	·98654	·99244
65	·95962	·96288	·96620	·96959	·97309	·97688	·98106	·98594	·99194
70	·95802	·96143	·96484	·96836	·97203	·97596	·98028	·98527	·99134
75	·95638	·95987	·96344	·96708	·97086	·97495	·97943	·98454	·99066
80	·95467	·95826	·96192	·96568	·96963	·97385	·97845	·98367	·98991

Experiments were made, by direction of the committee, to verify Gilpin's tables, which showed that the error introduced in ascertaining the strength of spirits by tables founded on Gilpin's numbers must be quite insensible in the practice of the revenue. The discrepancies thus detected, on a mixture of a given strength, did not amount in any one instance to unity in the fourth place of decimals. From a careful inspection of such documents the committee are of opinion, that Gilpin's tables possess a degree of accuracy far surpassing what could be expected, and sufficiently perfect for all practical or scientific purposes.

The following table is given by Mr. Lubbock, for converting the *apparent* specific gravity, or *indication*, into true specific gravity.

Indication.	—				Temperature.					+			Indication.
	30°	32°	3[illegible]	42°	47°	52°	57°	62°	67°	72°	77°	80°	
·82	·00083	·00078	·00065	·00052	·00039	·00025	·00012		·00011	·00024	·00035	·00042	·82
·83	·00084	·00079	·00066	00052	·00039	·00026	·00012		·00012	·00024	·00036	·00042	·83
·84	00085	·00080	·00066	00053	·00039	·00026	00013		·00012	·00024	·00036	·00043	·84
·85	·00086	·00081	·00067	·00054	·00040	·00026	·00013		·00012	00025	·00037	·00043	85
·86	·00087	·00082	00068	·00054	00040	·00027	·00013		·00012	00025	·00037	·00044	·86
·87	·00088	·00083	00069	·00055	·00041	·00027	·00013		·00012	·00025	00037	00044	87
·88	·00089	·00084	·00070	·00055	·00041	·00027	·00013		·00012	·00026	00038	·00045	88
·89	·00090	·00085	·00070	·00055	·00042	·00028	·00013		00012	·00026	·00038	·00045	·89
·90	·00091	·00085	·00071	·00056	·00042	·00028	·00014		·00013	00026	·00039	·00046	90
·91	·00092	·00086	·00072	·00057	·00043	·00028	·00014		·00013	·00026	·00039	·00046	·91
·92	·00093	·00087	·00073	·00058	·00043	00029	·00014		00013	·00027	·00040	·00047	·92
·93	·00094	·00088	00073	·00059	·00044	·00029	·00014		·00013	·00027	·00040	·00047	·93
·94	00095	·00089	·00074	·00059	·00044	·00029	·00014		00013	·00027	·00040	·00048	·94
·95	00096	·00090	·00075	·00060	·00045	·00029	·00014		·00013	·00028	·00041	00048	·95
·96	00097	·00091	00076	·00060	·00045	·00030	·00014		·00013	·00028	·00041	·00049	·96
·97	·00098	·00092	·00077	·00061	·00046	·00030	·00015		·00014	·00028	·00042	·00049	·97
·98	·00099	·00093	00077	·00062	·00046	·00030	·00015		·00014	00028	·00042	·00050	·98
·99	·00100	·00094	·00078	·00062	·00047	·00031	·00015		·00014	·00029	·00043	·00050	·99
·100	·00101	·00095	·00079	·00063	00047	·00031	·00015						100

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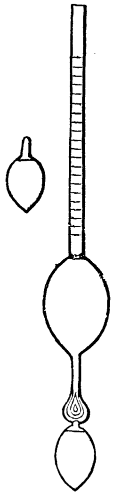
The hydrometer constructed, under the directions of the Commissioners of Excise, by Mr. Bate, has a scale of 4 inches in length divided into 100 parts, and 9 weights. It has thus a range of 900 divisions, and expresses specific gravities at the temperature of 62° Fahr. In order to render this instrument so accurate a measurer of the specific gravity, at the standard temperature, as to involve no error of an appreciable amount, Mr. Bate has constructed the weights (which in this instrument are immersed in the fluid of different specific gravities) so that each successive weight should have an increase of bulk over the preceding weight equal to that part of the stem occupied by the scale and an increase of weight sufficient to take the whole of the scale, and no more, down to the liquid. This arrangement requires great accuracy of workmanship, and enhances the price of the instrument. But it allows of increased strength in the ball, where it is very much required, and it gives, upon inspection only, the indication (apparent specific gravity) by which the general table is to be examined and the result ascertained. Fig. 5 represents this instrument and two of its nine ballast weights. It comprehends all specific gravities between 820 and 1000. It indicates true specific gravity with almost perfect accuracy at the temperature of 62° Fahr.; but it does not exclude other instruments from being used in conjunction with tables. The latter are, in fact, independent of the instrument, and may be used with gravimeters, or any instrument affording indications by specific gravity at a given temperature. See Spirits.

Fig. 5.



The commercial value of spirituous liquors being much lower in France than in England, a less sensible instrument becomes sufficient for the wants of that country. Baumé's and Cartier's hydrometers, with short arbitrary scales, are very much employed, but they have been lately superseded by an ingenious and ready instrument contrived by M. Gay Lussac, and called by him an *alcoomètre*. He takes for the term of comparison pure alcohol by volume, at the temperature of 15° Cent., and represents the strength of it by 100 *centimes*, or by unity. Consequently, the strength of a spirituous liquid is the number of centimes in volume of pure alcohol which that liquid contains at the temperature of 15° Cent. The instrument is formed like a common hydrometer, and is graduated for the temperature of 15° Cent. Its scale is divided into 100 parts or degrees, each of which denotes a centime of alcohol; the division 0 at the bottom of the stem corresponds to pure water, and the division 100 at its top, to pure alcohol. When immersed in a spirituous liquor at 15° Cent. (59° Fahr.) it announces its strength directly. For example: if in spirits supposed at the temperature of 15° Cent. it sinks to the division 50, it indicates that the strength of this liquor is 50 per cent., or that it contains 50 centimes of pure alcohol. In our new British proof spirit, it would sink to nearly 57, indicating 57 by volume of pure alcohol, allowing for condensation, or 50 by weight. A table of correction is given for temperature, which he calls "Table of real strength of spirituous liquors." The first vertical column of this table contains the temperatures, from 0° to 30° Cent., and the first horizontal line the indications of the alcoomètre. In the same table we have most ingeniously inserted a correction for the volume of the spirits when the temperature differs from 15° Cent. If we take 1000 litres or gallons, measured at the temperature of 2°, of a spirituous liquor whose apparent strength is 44^{c}; its real strength at 15° will from the preceding mode of correction be 49^{c}. On heating this liquid to 15°, in order to find its real specific gravity or strength, its bulk will become greater; and, instead of 1000 litres or gallons, which it measured at 2°, we shall have 1009 at 15° C. This number is inscribed in smaller characters in the same square cell with the real force, precisely under 49^{c}. All the numbers in small characters, printed under each *real strength*, indicate the volume which 1000 litres of a spirituous liquor would have, when measured at the temperature at which its apparent strength is taken. In the above example, the quantity in litres or gallons of pure alcohol contained in 1000 litres or gallons of the spirits, measured at the temperature of 2°, will be, therefore,—1009 lit. × 0·49 = 494 lit. 41.

This quantity of pure alcohol, thus estimated, is called *richness of spirit in alcohol*, or simply *richness*.

Let us take an example similar to the preceding, but at a higher temperature than 15° Cent. Suppose we have 1000 litres measured, at the temperature of 25°, of spirits whose apparent strength is 53^{c}, what is the real quantity of pure alcohol which this spirit contains at the temperature of 15°? We shall find in the table, first of all, that the real strength of the spirits is 49^{c}·3. As to its bulk or volume, it is very clear that the 1000 litres in cooling from 25° to 15°, will occupy a smaller space. This volume will be 993 litres; it is inscribed directly below 49^{c}·3, the real strength. We shall therefore have of pure alcohol, contained in the 1000 litres of spirits, measured a the temperature of 25°, or their *richness*, 993 lit. × 0·493 = 489 lit. 55.

Alcometrical Table of real Strength, by M. Gay Lussac.

Temperature. C.	31c	32c	33c	34c	35c	36c	37c	38c	39c	40c
Deg. 10	33·0 1002	34 1002	35 1003	36 1003	37 1003	38 1003	39 1003	40 1003	41 1003	42 1003
11	32·6 1002	33·6 1002	34·6 1002	35·6 1002	36·6 1002	37·6 1002	38·6 1002	39·6 1002	40·6 1003	41·6 1003
12	32·2 1001	33·2 1001	34·2 1002	35·2 1002	36·2 1002	37·2 1002	38·2 1002	39·2 1002	40·2 1002	41·2 1002
13	31·8 1001	32·8 1001	33·8 1001	34·8 1001	35·8 1001	36·8 1001	37·8 1001	38·8 1001	39·8 1001	40·8 1001
14	31·4 1001	32·4 1001	33·4 1001	34·4 1001	35·4 1001	36·4 1001	37·4 1001	38·4 1001	39·4 1001	40·4 1001
15	31 1000	32 1000	33 1000	34 1000	35 1000	36 1000	37 1000	38 1000	39 1000	40 1000
16	30·6 1000	31·6 1000	32·5 999	33·5 999	34·5 999	35·5 999	36·5 999	37·5 999	38·5 999	39·5 999
17	30·2 999	31·2 999	32·1 999	33·1 999	34·1 999	35·1 999	36·1 999	37·1 999	38·1 999	39·1 999
18	29·8 999	30·8 999	31·7 998	32·7 998	33·7 998	34·7 998	35·7 998	36·7 998	37·7 998	38·7 998
19	29·4 998	30·4 998	31·3 998	32·3 998	33·3 998	34·3 998	35·3 998	36·3 998	37·3 997	38·3 997
20	29 998	30 998	30·9 997	31·9 997	32·9 997	33·9 997	34·9 997	35·9 997	36·9 997	37·9 997
21	28·6 997	29·6 997	30·5 997	31·5 997	32·5 997	33·5 997	34·5 997	35·5 996	36·5 996	37·5 996
22	28·2 997	29·2 997	30·1 996	31·1 996	32·1 996	33·1 996	34·1 996	35·1 996	36·1 996	37·1 996
23	27·8 996	28·8 996	29·7 996	30·7 996	31·7 996	32·7 996	33·7 996	34·7 995	35·7 995	36·7 995
24	27·4 996	28·4 996	29·3 995	30·3 995	31·3 995	32·3 995	33·3 995	34·3 995	35·3 995	36·3 994
25	27 995	28 995	28·9 995	29·9 995	30·9 995	31·9 994	32·9 994	33·9 994	34·9 994	35·9 994

Temperature. C.	41c	42c	43c	44c	45c	46c	47c	48c	49c	50c
Deg. 10	43 1003	44 1004	45 1004	46 1004	46·9 1004	47·9 1004	48·9 1004	49·9 1004	50·9 1004	51·8 1004
11	42·6 1003	43·6 1003	44·6 1003	45·6 1003	46·6 1003	47·6 1003	48·6 1003	49·5 1003	50·5 1003	51·5 1003
12	42·2 1002	43·2 1002	44·2 1002	45·2 1002	46·2 1002	47·2 1002	48·2 1002	49·2 1002	50·2 1002	51·1 1002
13	41·8 1001	42·8 1001	43·8 1001	44·8 1002	45·8 1002	46·8 1002	47·8 1002	48·8 1002	49·8 1002	50·8 1002
14	41·4 1001	42·4 1001	43·4 1001	44·4 1001	45·4 1001	46·4 1000	47·4 1001	48·4 1001	49·4 1001	50·4 1000
15	41 1000	42 1000	43 1000	44 1000	45 1000	46 1000	47 1000	48 1000	49 1000	50 1000
16	40·6 999	41·6 999	42·6 999	43·6 999	44·6 999	45·6 999	46·6 999	47·6 999	48·6 999	49·6 999

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Alcometrical Table of real Strength, by M. Gay Lussac (*continued*).

Temperature. C.	41c	42c	43c	44c	45c	46c	47c	48c	49c	50c
Deg. 17	40·2 999	41·2 999	42·2 999	43·2 998	44·9 998	45·2 998	46·2 998	47·2 998	48·2 998	49·2 998
18	39·8 998	40·8 998	41·8 998	42·8 998	43·8 998	44·9 998	45·9 998	46·9 998	47·9 998	48·9 998
19	39·4 997	40·4 997	41·4 997	42·5 997	43·5 997	44·5 997	45·5 997	46·5 997	47·5 997	48·5 997
20	39 997	40 997	41 997	42·1 997	43·1 996	44·1 996	45·1 996	46·1 996	47·2 996	48·2 996
21	38·6 996	39·6 996	40·6 996	41·7 996	42·7 996	43·7 996	44·8 996	45·8 996	46·8 995	47·8 995
22	38·2 996	39·2 995	40·2 995	41·3 995	42·3 995	43·3 995	44·3 995	45·3 995	46·4 995	47·4 995
23	37·8 995	38·8 995	39·8 995	40·9 994	41·9 994	42·9 994	43·9 994	44·9 994	46 994	47 994
24	37·4 994	38·4 994	39·4 994	40·5 994	41·5 994	42·5 994	43·6 994	44·6 994	45·6 993	46·6 993
25	37 994	38 994	39 993	40·1 993	42·1 993	42·2 993	43·2 993	44·2 993	45·2 993	46·3 993

Temperature. C.	51c	52c	53c	54c	55c	56c	57c	58c	59c	60c
Deg 10	52·8 1004	53·8 1004	54·8 1004	55·8 1004	56·8 1004	57·8 1004	58·8 1004	59·7 1004	60·7 1004	61·7 1004
11	52·5 1003	53·5 1003	54·4 1003	55·4 1003	56·4 1003	57·4 1003	58·4 1003	59·4 1003	60·4 1003	61·4 1003
12	52·1 1002	53·1 1002	54·1 1002	55 1002	56 1002	57 1002	58 1002	59 1002	60 1002	61 1002
13	51.8 1002	52·7 1002	53·7 1002	54·7 1002	55.7 1002	56·7 1002	57·7 1002	58·7 1002	59·7 1002	60·7 1002
14	51·4 1001	52·3 1001	53·3 1001	54·3 1001	55·3 1001	56·3 1001	57·3 1001	58·3 1001	59·3 1001	60·3 1001
15	51 1000	52 1000	53 1000	54 1000	55 1000	56 1000	57 1000	58 1000	59 1000	60 1000
16	50·6 999	51·6 999	52·6 999	53·6 999	54·6 999	55·6 999	56·6 999	57·6 999	58·6 999	59·6 999
17	50·3 998	51·3 998	52·3 998	53·3 998	54·3 998	55·3 998	56·3 998	57·3 998	58·3 998	59·3 998
18	49·9 998	50·9 998	51·9 998	52·9 998	53·9 998	54·9 998	55·9 998	56·9 997	57·9 997	58·9 997
19	49·5 997	50·6 997	51·6 997	52·6 997	53·6 997	54·6 997	55·6 997	56·6 997	57·6 997	58·6 997
20	49·2 996	50·2 996	51·2 996	52·2 996	53·2 996	54·2 996	55·2 996	56·2 996	57·2 996	58·2 996
21	48·8 995	49·8 995	50·8 995	51·8 995	52·9 995	53·9 995	54·9 995	55·9 995	56·9 995	57·9 995
22	48·4 995	49·4 995	50·4 995	51·4 994	52·5 994	53·5 994	54·5 994	55·5 994	56·5 994	57·5 994
23	48 994	49·1 994	50·1 994	51·1 994	52·1 994	53·1 994	54·1 994	55·1 993	56·1 993	57·1 993
24	47·6 993	48·7 993	49·7 993	50·7 993	51·8 993	52·8 993	53·8 993	54·8 993	55·8 993	56·8 992
25	47·3 992	48·3 992	49·3 993	50·3 992	51·4 992	52·4 992	53·4 992	54·4 992	55·5 992	56·5 992

Alcometrical Table of real Strength, by M. Gay Lussac (*continued*).

Temperature. C.	61c	62c	63c	64c	65c	66c	67c	68c	69c	70c
Deg. 10	62·7 1004	63·7 1004	64·7 1004	65·7 1004	66·7 1004	67·6 1004	68·6 1004	69·6 1004	70·6 1004	71·6 1004
11	62·4 1003	63·4 1003	64·4 1003	65·4 1003	66·4 1003	67·3 1003	68·3 1003	69·3 1004	70·3 1004	71·3 1004
12	62 1002	63 1002	64 1002	65 1002	66 1002	67 1002	68 1003	69 1003	70 1003	71 1003
13	61.7 1002	62·7 1002	63·7 1002	64·7 1002	65 7 1002	66·7 1002	67·7 1002	68·7 1002	69·6 1002	70·6 1002
14	61·3 1001	62·3 1001	63·3 1001	64·3 1001	65·3 1001	66·3 1001	67·3 1001	68·3 1001	69·3 1001	70·3 1001
15	61 1000	62 1000	63 1000	64 1000	65 1000	66 1000	67 1000	68 1000	69 1000	70 1000
16	60·6 999	61·7 999	62·7 999	63·7 999	64·7 999	65·7 999	66·7 999	67·7 999	68·7 999	69·7 999
17	60·3 998	61·3 998	62·3 998	63·3 998	64·3 998	65·3 998	66·3 998	67·3 998	68·3 998	69·3 998
18	59·9 997	61 997	62 997	63 997	64 997	65 997	66 997	67 997	68 997	69 997
19	59·6 997	60·6 997	61·6 997	62·7 997	63·7 997	64·7 997	65·7 997	66·7 997	67·7 996	68·7 996
20	59·2 996	60·3 996	61·3 996	62·3 996	63·3 996	64·3 996	65·4 996	66·4 996	67·4 996	68·4 996
21	58·9 995	59·9 995	61 995	62 995	63 995	64 995	65 995	66 995	67 995	68·1 995
22	58·5 994	59·5 994	60·6 994	61·6 994	62·7 994	63·7 994	64·7 994	65·7 994	66·7 994	67·8 994
23	58·1 993	59·2 993	60·2 993	61·3 993	62·3 993	63·3 993	64·3 993	65·4 993	66·4 993	67·4 993
24	57·8 992	58·9 992	59·9 992	61 992	62 992	63 992	64 992	65 992	66 992	67·1 992
25	57·5 992	58·5 992	59·5 992	60·6 991	61·6 991	62·6 991	63·7 991	64·7 991	65·7 991	66·7 991

Temperature. C.	71c	72c	73c	74c	75c	76c	77c	78c	79c	80c
Deg. 10	72·6 1004	73·5 1004	74·5 1005	75·5 1005	76·5 1005	77·5 1005	78·5 1005	79·5 1005	80·5 1005	81·5 1005
11	72·3 1004	73·2 1004	74·2 1004	75·2 1004	76·2 1004	77·2 1004	78·2 1004	79·2 1004	80·2 1004	81·2 1004
12	72 1003	72·9 1003	73·9 1003	74·9 1003	75·9 1003	76·9 1003	77·9 1003	78·9 1003	79·9 1003	80·9 1003
13	71·6 1002	72·6 1002	73·6 1002	74·6 1002	75·6 1002	76·6 1002	77·6 1002	78·6 1002	79·6 1002	80·6 1002
14	71·3 1001	72·3 1001	73·3 1001	74·3 1001	75·3 1001	76·3 1001	77·3 1001	78·3 1001	79·3 1001	80·3 1001
15	71 1000	72 1000	73 1000	74 1000	75 1000	76 1000	77 1000	78 1000	79 1000	80 1000
16	70·7 999	71·7 999	72·7 999	73·7 999	74·7 999	75·7 999	76·7 999	77·7 999	78 7 999	79·7 999
17	70·3 998	71·3 998	72·3 998	73·3 998	74·3 998	75·4 998	76·4 998	77·4 998	78·4 998	79.4 998

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Alcometrical Table of real Strength, by M. Gay Lussac (*continued*).

Temperature. C.	71c	72c	73c	74c	75c	76c	77c	78c	79c	80c
Deg. 18	70 997	71 997	72 997	73 997	74 997	75·1 997	76·1 997	77·1 997	78·1 997	79·1 997
19	69·7 996	70·7 996	71·7 996	72·7 996	73·7 996	74·7 996	75·8 996	76·8 996	77·8 996	78·8 996
20	69·4 996	70·4 996	71·4 995	72·4 995	73·4 995	74·4 995	75·5 995	76·5 995	77·5 995	78·5 995
21	69·1 995	70·1 995	71·1 995	72·1 994	73·1 994	74·1 994	75·2 994	76·2 994	77·2 994	78·2 994
22	68·8 994	69·8 994	70·8 994	71·8 994	72·8 993	73·8 993	74·8 993	75·9 993	76·9 993	77·9 993
23	68·4 993	69·4 993	70·5 993	71·5 993	72·5 992	73·5 992	74·5 992	75·5 992	76·6 992	77·6 992
24	68·1 992	69·1 992	70·1 992	71·2 992	72·2 992	73·2 992	74·2 992	75·2 991	76·3 991	77·3 991
25	67·8 991	68·8 991	69·8 991	70·8 991	71·8 991	72·8 991	73·9 991	74·9 991	76 991	77 991

Temperature. C.	81c	82c	83c	84c	85c	86c	87c	88c	89c	90c
Deg. 10	82·4 1005	83·4 1005	84·4 1005	85·4 1005	86·4 1005	87·4 1005	88·3 1005	89·3 1005	90·2 1005	91·2 1005
11	82·2 1004	83·1 1004	84·1 1004	85·1 1004	86·1 1004	87·1 1004	88 1004	89 1004	90 1004	91 1004
12	81·9 1003	82·9 1003	83·9 1003	84·8 1003	85·8 1003	86·8 1003	87·8 1003	88·7 1003	89·7 1003	90·7 1003
13	81.6 1002	82·6 1002	83·6 1002	84·6 1002	85·5 1002	86·5 1002	87·5 1002	88·5 1002	89·5 1002	90·5 1002
14	81·3 1001	82·3 1001	83·3 1001	84·3 1001	85·3 1001	86·3 1001	87·3 1001	88·2 1001	89·2 1001	90·2 1001
15	81 1000	82 1000	83 1000	84 1000	85 1000	86 1000	87 1000	88 1000	89 1000	90 1000
16	80·7 999	81·7 999	82·7 999	83·7 999	84·7 999	85·7 999	86·7 999	87·7 999	88·7 999	89·7 999
17	80·4 998	81·4 998	82·4 998	83·4 998	84·4 998	85·4 998	86·4 998	87·4 998	88·4 998	89·5 998
18	80·1 997	81·1 997	82·1 997	83·1 997	84·1 997	85·2 997	86·2 997	87·2 997	88·2 997	89·2 997
19	79·8 996	80·8 996	81·9 996	82·9 996	83·9 996	84·9 996	85·9 996	86·9 996	87·9 996	88·9 996
20	79·5 995	80·5 995	81·6 995	82·6 995	83·6 995	84·6 995	85·6 995	86·6 995	87·7 995	88·7 995
21	79·2 994	80·2 994	81·3 994	82·3 994	83·3 994	84·3 994	85·3 994	86·4 994	87·4 994	88·4 994
22	78·9 993	79·9 993	81 993	82 993	83 993	84 993	85 993	86·1 993	87·1 993	88·2 993
23	78·6 992	79·6 992	80·7 992	81·7 992	82·7 992	83·8 992	84·8 992	85·8 992	86·8 992	87·9 992
24	78·3 991	79·3 991	80·4 991	81·4 991	82·4 991	83·5 991	84·5 991	85·5 991	86·5 991	87·6 991
25	78 991	79 991	80·1 990	81·1 990	82·1 990	83·2 990	84·2 990	85·2 990	86·3 990	87·4 990

I consider the preceding table, which I have extracted from the longer tables o M. Gay Lussac, as an important addition to the resources of British dealers and manufacturing chemists. With the aid of his little instrument, which may be got for a trifle from its ingenious maker, M. Collardeau, Rue Fauburg St. Martin at Paris, cr constructed by one of the London hydrometer artists, the per centage of real alcohol, and the real value of any spirituous liquor, may be determined to sufficient nicety for most purposes, in a far easier manner than by any instruments now used in this country. It has been adopted by the Swedish government, with M. Gay Lussac's tables.

M. Gay Lussac's table gives, by inspection, the true bulk of the spirits as corrected for temperature; that is their volume, if of the normal temperature of 15° Cent. (59° Fahr). Now this is important information; for, if a person buys 1000 gallons of spirits in hot weather, and pays for them exactly according to their strength corrected for temperature, he will not have 1000 gallons when the weather is in its mean state. He may lose, in this way, several gallons, without being aware of it from his hydrometer.

Sometimes, after moist autumns, when damaged grain abounds, the alcohol distilled from its fermented wash contains a peculiar volatile body. When we apply our nose to this species of spirits in its hot state, the volatile substance dissolved in it irritates the eyes and nostrils; it has very nearly the same smell as an alcoholic solution of cyanogen, as any chemist may discover by standing near the discharge pipe of the refrigeratory worm of a raw-grain whisky still. Such spirits intoxicate more strongly than pure spirits of the same strength, and excite, in many persons, even temporary frenzy. It is a volatile fatty matter, of a very fetid odor, when obtained by itself, as I have procured it in cold weather at some of the great distilleries in Scotland. It does not combine with bases. At the end of a few months, it spontaneously decomposes in the spirits and leaves them in a less nauseous and noxious state. By largely diluting the spirits with water, and distilling at a moderate temperature, the greater part of this oil may be separated. Part of it comes over with the strongest alcohol, and part with the latter runnings, which are called by the distillers strong and weak feints. The intermediate portion is purer spirit. The feints are always more or less opalescent, or become so on dilution with water, and then throw up an oily pellicle upon their surface. The charcoals of light wood, such as pine or willow, well calcined, and infused in sufficient quantity with the spirits prior to rectification, will deprive them of the greater part of that oily contamination. Animal charcoal, well calcined, has also been found useful; but it must be macerated for some time with the empyreumatic spirits, before distillation. Another mode of separating that offensive oil is, to agitate the impure spirits with a quantity of a fat oil, such as olive oil, or oil of almonds, to decant off the oil, and re-distil the spirits with a little water.

Digestion and agitation with calcined magnesia, for some time, followed by filtration and distillation, are also good means of improving the flavor of alcohol. The taste of the oil of grains is best recognized by agitation with water, whereby, on standing, the diluted spirit throws up a film of oil, visible by reflected light. If the spirit be mixed with a few drops of nitrate of silver and exposed for some time to sunshine, the oil will react upon the oxide of silver, and cause a brown tinge; but if there be no oil present, the spirits will remain limpid. If one part of hydrate of potash, dissolved in a little water, be mixed with 160 parts of spirits, and if the mixture be well shaken, then slowly evaporated down to 15 parts and mixed with 15 parts of dilute sulphuric acid in a phial, to be then corked, there will soon exhale from the mixture a peculiar offensive odor, characteristic of the quality and origin of the impure spirit, whether obtained from raw grain, from malt, from potatoes, rye, arrack, rum, brandy, &c. This excellent process may be used also for testing wines. Lime and alkalis always injure the flavor of ardent spirits of all kinds.

Some foreign chemists direct empyreumatic or rank spirits to be rectified with the addition of chloride of lime. I have tried this method in every way, and on a considerable scale, but never found the spirits to be improved by it. They were rather deteriorated. See Brandy, Distillation, Fermentation, Gin, Rum, and Whisky.

Anhydrous or absolute alcohol, when swallowed, acts as a mortal poison, not only by its peculiar stimulus on the nervous system, but by its abstracting the aqueous particles from the soft tissue of the stomach, with which it comes in contact, so as to destroy its organization.

The absence of water in alcohol may be tested by sulphate of copper calcined to whiteness, which imparts a blue tinge to the liquid. 46 parts of. absolute alcohol contain 6 parts of hydrogen; and hence, by being burnt in a tubulated globular receiver connected with a condensing worm, they afford 54 parts of water. If the spirit was free from oil, the water will be quite pure, as the carbonic acid flies off.

The high price of alcohol in this country, in consequence of the heavy fiscal duties, and its low price in most other countries, where it is nearly duty free, has led to its contraband importation under various disguises. Sometimes it is introduced under the mask of oil of turpentine, from which it can be sufficiently freed by rectification for the purpose of the gin manufacturers. Sometimes it is disguised with wood naphtha, or wood vinegar; from the latter of which it may be separated by distillation in a water bath; but from the former it is more difficult to extricate it, as alcohol and wood spirit are nearly equally volatile. It has also been disguised with coal naphtha; but from this it may be easily separated by distillation, on account of the great difference between the boiling points of the two liquids; besides, coal naphtha will not combine with water, as alcohol does.

When the object is to discover whether wood spirit contains alcohol, we may proceed as follows:—Add to the suspected liquid a little nitric acid, of specific gravity 1·45. If alcohol be present, in even small proportion, an effervescence will ensue, from the evolution of etherised nitrous gas, with its characteristic ethereous smell. On treating the mixture with a nitrous solution of mercury, as in the process for fulminate of mercury, an effervescence will take place, the dense vapor of etherised mercurial gas will appear, and a certain proportion of fulminate will be formed, corresponding pretty closely to the proportion of alcohol in the wood naphtha mixture.

As the boiling point of wood spirit is only about 145°, while that of alcohol, of like specific gravity (0·825), is 173° F., a good criterion of the proportion of the two liquids present in the mixture may be found in its boiling temperature.

Pure wood spirit, when mixed with the above nitric acid, becomes of a ruby tint, but remains tranquil. Alcohol continues colorless, but enters into violent ebullition, and is nearly all dissipated in fumes.

Alcohol diluted with water has a less resultant density than wood spirit of like strength similarly diluted. While alcohol thus becomes of 0·920, wood spirit becomes 0·926 or 0·927.

If wood spirit be contained in alcohol, it may be detected to the greatest minuteness by the test of caustic potash, a little of which, in powder, causing wood spirit to become speedily yellow and brown, while it gives no tint to alcohol. Thus 1 per cent. of wood spirit may be discovered in any sample of spirits of wine. For further details upon this analytical inquiry, see my pamphlet entitled *The Revenue in Jeopardy.*

ALDEHYDE; a name compounded out of *alcohol dehydrogenated*, being a substance formed by depriving alcohol of its hydrogen. The process is too intricate for description here. It is a limpid liquid, of 0·790 specific gravity, boiling at 21·8° C., and not reddening litmus. It has a peculiar ethereous smell: when its vapor is inhaled it causes suffocation, and even in small quantities a spasmodic constriction of the thorax. It is composed of 4 atoms of carbon = 24, 4 of hydrogen = 4, and 2 of oxygen = 16; or in 100 of 54·55, 9·09 and 36·36 respectively. It is very inflammable.

ALE. The fermented infusion of pale malted barley, combined with infusion of hops. See Beer.

ALEMBIC, a Still; which see.

ALEMBROTH, salt of. The salt of wisdom, of the alchemists; a compound of bichloride of mercury and sal ammoniac, from which the old white precipitate of mercury is made.

ALGAROTH, powder of. A compound of oxide and chloride of antimony, being a precipitate obtained by pouring water into the acidulous chloride of that metal.

ALGAROVILLA. This substance is called by the Spaniards *Algaroba*, from the resemblance it bears to the fruit of the Carob (*Ceratonia siliqua*), which is a native of Europe, in the southern countries of Spain and Portugal. The substance lately analysed by me is the fruit of a tree which grows in Chili, of which the botanical name is *Prosopis pallida*, according to Captain Bagnald, R.N., who first brought a sample of it to this country in the year 1832. It consists of pods bruised and agglutinated more or less with the extractive exudation of the seeds and husks. According to a more recent determination, algarovilla is said to be the product of the tree Juga Marthæ of Santa Martha, a province of New Carthagena.

It is an astringent substance replete with tannin, capable, by its infusion in water, of tanning leather, for which purpose it possesses more than four times the power of good oak bark. Its active matter is very soluble in water at a boiling temperature. The seeds are merely nutritive and demulcent, but contain no astringent property. This resides in the husks. The seeds in the entire pod constitute about 1-5th of the weight, and they are three or four in number in each oblong pod. Alcohol of 60 per cent. over proof dissolves 64 parts in 100 of this substance. The solution consists chiefly of tannin, with a very little resinous matter. Water dissolves somewhat more of it, and affords a very styptic-tasted solution, which precipitates solution of isinglass very copiously, like infusion of galls and catechu. Its solution forms with sulphate of iron a black precipitate, which is kept floating by means of the gum present, and thereby constitutes good ink. My report to the merchant was written with a combination thus made, in proportions taken at random; and there is no doubt that by using a stronger decoction of the algarovilla, along with a proper proportion of copperas, an excellent black ink might be prepared without any other addition.

I find that a decoction of the algarovilla affords with cotton cloth, mordanted with tin solution, as also with acetate of alumina liquor, a brilliant yellow dye; the former being the brighter and fuller of the two.

A tincture of algarovilla might be used as an astringent in medicine; or probably a decoction of the whole substance would be preferable, on account of the demulcent quality of the seeds when bruised. As an article of commerce it cannot be rated at a high price, nor should it pay much duty till its value as an article of manufactures or medicine be fully ascertained.

ALIZARINE. See Madder.

ALKALI. A class of chemical bodies, distinguished chiefly by their solubility in water, and their power of neutralizing acids, so as to form saline compounds. The alkalis of manufacturing importance are, ammonia, potash, and soda. These alkalis change the purple color of red cabbage and radishes to a green, the reddened tincture of litmus to a purple, and the color of turmeric and many other yellow dyes to a brown. Even when combined with carbonic acid, the three alkalis exercise this discoloring power, which the alkaline earths, lime, and barytes, do not. The same three alkalis have an acrid, and somewhat urinous taste; the first two are energetic solvents of animal matter; and the three combine with oils so as to form soaps. They unite with water in every proportion, and also with alcohol; and the three combine with water after being carbonated.

ALKALI—ORGANIC; or organic bases. Many plants and ingredients of plants which exercise a powerful specific operation upon the living system of man and other animals contain peculiar combinations which have in chemistry a decidedly alkaline reaction; and have hence been called alkaloids. They unite directly with both hydrogen and oxygen acids, and in this respect differ essentially from methyloxide, aethyloxide, and amyloxide. Sertürnier was the first discoverer of these bases, having recognised in opium the alkaloid now called morphia. Soon afterwards Pelletier and Caventou discovered analogous bases in the strychnos nux vomica, as also in white hellebore. As these bases possessed in a remarkable degree the peculiar action of each plant upon the human system, chemists set themselves diligently to search in the poisonous and narcotic extracts for similar principles. From the discovery, however, of quinia, cinchonia, piperine, &c., it appeared, that not only the poisonous ingredients of plants, but others possessed of peculiar medicinal qualities, constituted peculiar alkaloids. These occur in plants always combined with organic acids, which are also often of a peculiar nature. Thus the base of opium occurs combined with meconic acid, and the base of chelidonium with chelidonic acid. The acid constituent, however, is often the malic or one of the forms of the tannic.

Wöhler first made the discovery that through the decomposition of cyanate of ammonia urea was formed, which possessed the property of combining with several acids, especially the nitric and oxalic, under like conditions with the bases existing in nature. Unverdorben extracted from animal empyreumatic oil several basic compounds, such as odorine, ammoline, &c., and Runge out of coal-tar obtained kyanol and leukol. Fritszche obtained by the decomposition of anthranilic acid, aniline, whose identity with kyanol has been since shown by Hofmann. Zinin made the discovery that by the operation of sulphuretted hydrogen upon nitrobenzide and upon nitronaphtalide, certain organic bases were formed with separation of sulphur, such as aniline, benzidine, naphtalidine, &c. Laurent discovered lophine and amarine, bases which result through the operation of ammonia upon oil of bitter almonds. Thiosinnamine is formed by the action of ammonia upon the volatile oil of mustard, &c.

Composition of alkaloids or organic bases.—The whole of these bases contain nitrogen combined with carbon and hydrogen, and most of them contain also oxygen. These alkaloids combine also with hydrogen and oxygen acids, as ammonia does, and thereby are distinguished essentially from aethyloxide, methyloxide, and amyloxide. If we reckon ammonia as a hydrogen basis, the organic bases must belong to the same category. Their oxygen constituent does not correspond to their capacity of saturation, which follows from the fact, that alkaloids exist which are free from oxygen.

The production of the organic bases is different according as they belong to volatile or non-volatile bodies. The volatile may be obtained when the plants in which they exist are distilled with a somewhat dilute potash lye. The distilled liquor contains always besides the organic base a little ammonia. It is to be exactly saturated with sulphuric acid, then evaporated by gentle heat, and the remainder treated with absolute alcohol or with ether, in which the sulphuric salt of the organic base dissolves. This solution is to be mixed with water, the spirit is to be distilled off, the remainder decomposed with potash lye, next agitated with ether, which dissolves out the alkaloid, which remains after the evaporation of the ether. In this way nicotine is obtained. The non volatile bases are commonly obtained by extracting the constituents of the plant with water acidulated with sulphuric or muriatic acid, and from the concentrated solution precipitating the bases by means of an alkaline substance, such as potash, lime, ammonia, or magnesia. The precipitate is to be dried and boiled in alcohol, which dissolves the alkaloid. This may be purified by repeated crystallizations aided by animal charcoal, &c.

ALKALIMETER. An instrument for measuring the alkaline force or purity of any of the alkalis of commerce. It is founded on the principle, that the quantity of real alkali present in any sample is proportional to the quantity of acid which a given weight of it can neutralize.

ALKALIMETRY. Nearly forty years have elapsed since I was led, by peculiar circumstances, to construct a very simple method of testing alkalis, the principle of which I soon afterward applied to acids, bleaching powder, dye-stuffs, and most other chemical substances extensively used in manufactures.* In 1814 and 1815, during the summer vacation of my Glasgow classes, I was engaged in delivering courses of lectures on chemistry in the Belfast Academical Institution, and had many of the most eminent members of the Linen Board of that town for my pupils. Being occasionally consulted upon the qualities of the alkalis, which were used to the value of 200,000*l.* by the linen bleachers of Ireland, I saw the importance to them of a simple alkalimetrical test, both for purchasing and for using their barillas and potashes. The following extract from the Belfast *News Letter*, of July 9th, 1816, will show the nature of my contrivance:—

> "This day one of the porters of the Linen Hall, Belfast, was called into the library-room at the request of Dr. Ure, who being quite unknown to Dr. Ure, and never having seen any experiments made with acids and alkalis, he took the instrument at our desire, which being filled with colored acid, by pouring it slowly on adulterated alkali, which we had previously prepared, he ascertained exactly the per-centage of genuine alkali in the mixture. Belfast, 25th June, 1816.
>
> "John S. Ferguson, Chairman.
> James M'Donnel, M. D.
> John M. Stoupe.
> S. Thomson, M. D."

Of these gentlemen, two were leading members of the Linen Board, and the others the two principal physicians of the town. The publication of the details of my method of alkalimetry was delayed till arrangements were made for its general introduction, under the direction of the Linen Board of Dublin, whose professor of chemistry, Mr. W. Higgins, as well as Dr. Barker, professor of chemistry in Trinity College, granted certificates of the "accuracy and the national importance" of the instrument. The alkaline matter then imported into Ireland was often largely contaminated with common salt, even to the extent of 80 or 90 per cent. During the procrastination of the Board, I lent my Treatise on Alkalimetry to Dr. Henry, of Manchester, who inadvertently published an account of it, though with reference to me, in the next edition of his *Elements of Chemistry*. Having, in the long interval since, contrived many modifications of the instrument, and having extended its principle to testing other articles I am induced to offer it now to the world, in consequence of the recent appearance of a publication upon the same subject, by two very ingenious chemists of Liebig's school, Drs. R. Fresenius and H. Will. Of their system of alkalimetry, &c., a copious abstract appeared in the *Annalen der Chimie und Pharmacie* for July last, and about the same time a pamphlet was published by Winter, at Heidelberg, under the title *Neue Verfahrungsweisen zur Bestimmung des Werthes der Pottasche und Soda, der Saüren, und des Braunstein;* or "New Processes for determining the Value of Potash and Soda, of Acids, and Black Oxide of Manganese." However accurate these processes may be, and however apt for a German or French student of chemistry, they are, in my apprehension, not at all fitted for the familiar use of manufacturers and dealers in any country, and certainly not for those of the United Kingdom.

Descroizilles was the first person who contrived an instrument, called an alkalimeter, to ascertain the alkaline strength of potash and soda, without much calculation. His method was described in the *Annales de Chimie* for 1806, tom. lx., and a translation of it appeared in our *Philosophical Magazine*, vol. xxviii., for July and August of the following year. His apparatus consisted of a glass tube, 8 or 9 inches long, and 7 or 8 lines in diameter, closed at one end, but terminated at the other in a kind of small funnel (with a beak or spout), connected to the tube by a narrow neck, having a calibre of two lines and a half. Upon the shoulder, under the throat, there was a hole for admitting air to the long tube in the act of being emptied, by sloping its mouth downward. This cylindrical vessel was to contain 38 grammes of water, which space was divided into 76 equal parts, which it was extremely important to proportion accurately. The liquor was prepared by taking concentrated sulphuric acid, at 66° Baumé (1·845 spec. grav.), and diluting it with nine times its weight of water. The instrument being poised in a balance, he introduced into it very exactly two grammes of the above test acid, and when the instrument stood upright, he scratched a line at the level of the liquor, and thus proceeded by addition of successive grammes to graduate the whole, till 36 were added, after which he subdivided these spaces by lines into 72 demi-gramme volumes. He then proceeds to describe eight different subsidiary articles required for his operations:—

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* Among others to nitrate of potash, nitrate of soda, and to white lead, either in powder or in paint. My nitrometer enables a person not at all versant in chemistry to ascertain in a quarter of an hour, but by two distinct processes, the quantity of pure nitrate in either of these salts, to one part in 200. The cerussa-meter is equally simple and expeditious.

"*Alkalimetrical trials of potash.*—Weigh exactly one demi-gramme of potash, put it into a glass, and pour upon it about four fifths of a decilitre of water; facilitate the solution of the potash by stirring it with a small chip of wood, three or four times in an hour and a half, a minute at each time. When the solution is effected, pour it into the small tin measure, No. 4, which is to be then filled up with water; pour it back again into the glass, in which you must still pour a measure full of pure water; stir this new mixture also three or four times within half an hour, in order to facilitate the precipitation of a slight sediment, which soon falls down. This sediment being completely formed, slope the glass with caution, in order to fill with clear liquor the small measure; then empty this last into another large glass; after this place round the edges of a plate drops of syrup of violets; pour also into the alkalimeter test liquor until the line marks 0; take it afterward with the left hand, inclining it upon the glass which contains the moiety of the clean alkaline solution: the acid liquor will fall into it by hasty drops, or in a very small thread, which you may moderate at pleasure, by retarding the entrance of the air at the lateral hole or vent, upon which must be placed the end of the finger; at the same time, with a small stick or match, assist the mixture and facilitate the development of the carbonic acid which is manifested by effervescence. When you have emptied the alkalimeter to about the line 40, try if the saturation approaches, by drawing your small stick from the mixture, and resting it upon the drops of syrup of violets, which should become green, if the potash is not of a very inferior quality. If, on the contrary, the violet color is not altered, or what would be worse, if it be changed into red, there would be, in the first case, an indication of saturation, and in the second a proof of super-saturation. But this is not the case with good potashes; at that line, the liquor tried can alter the syrup of violets into green only; or cause to return to the violet, and even to the green, the drops which had been changed into red at the time of a former trial; we must, therefore, in general add more acid, which occasions a new effervescence. This addition must always be made with caution, and we must touch every time a drop of syrup of violets in order to stop. When at last the latter assumes a red hue, then, after having restored the alkalimeter to a perpendicular position, in order to see at what line the testing liquor stops, you must reckon one degree less, in order to compensate the excess of saturation. The mean term of potashes is 56; this implies that they require for their saturation *fifty-five hundredths* of their weight of sulphuric acid."

For the analysis of commercial sodas of all kinds, M. Descroizilles prescribes using ten and a half deci-grammes of this alkali, instead of the ten deci-grammes for potashes, and proceeds as above detailed. In his table of results annexed, we find American potashes called 60° to 63°.

American pearlashes - - -	50° to 55°
Dantzic potash - - - -	45 to 55
Alicant soda - - - -	20 to 33

It is obvious, from these statements, that the alkalimeter so made and graduated denoted comparative, but not absolute, quantities of alkalis present in the commercial samples. The rest of his very long memoir is occupied with what he calls the graduation of potashes and sodas, the economy of their graduation, the proportions of carbonic acid in them, the processes of caustification, the presence of potash in all lime which is burnt by a wood fire, origin of neutral soda, and probable origin of natrum; without any more explicit instructions. The instrument, as left in this vague state, never was employed, nor could it come into use, among English manufacturers and dealers.

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The next alkalimeter, of which an account has been published, was my own. In constructing this instrument, I availed myself of the lights recently shed on chemical proportions by Dr. Dalton's atomic theory, and I thus made it to represent, not relative, but absolute measures of the amount of real alkali existing in any commercial sample. The test-liquor used at that time was sulphuric acid, which is most readily and accurately diluted to the requisite degree by means of a glass bead, very carefully made, of the specific gravity that the standard acid should have. In order to make the test-liquor, therefore, nothing more is requisite than to put the bead into distilled water, and to add to it somewhat dilute but pure sulphuric acid, slowly and with agitation, till the bead rises from the bottom, and floats in the middle of the liquor at the temperature of 60° Fahr. The delicacy of this means of adjustment is so great, that a single degree of increase of heat will cause the bead to sink to the bottom—a precision which no hydrometer can rival. The test-tube, about 14 inches long, contains generally 1,000 grains of water, and is graduated into 100 equal parts by means of equal measures of mercury. The test-liquor is faintly tinged with red cabbage or litmus; so that the change of color, as it approaches to the saturating pitch, on adding it to 100 grains of the commercial alkali, becomes a sure guide in conducting the experiment to a successful issue. One hundred measures of this test-liquor neutralize exactly 100 grains of absolute soda (oxide of sodium), and of course very nearly 150 of potash. A bead may also be adjusted for test-liquors, of which 1,000 grain measures neutralize 100 of potash, and therefore 66⅔ of soda, as well as other proportions, for special purposes of greater minuteness of research. One may be so graduated as to indicate clearly a difference of $\frac{1}{100}$ of a grain of ammonia. In making such nice experiments, it is of course requisite to free the alkaline matter beforehand from sulphurets, sulphites, and hyposulphites, by igniting it in contact with chlorate of potash, as long since recommended by Gay-Lussac. With such means in careful hands, all the problems of alkalimetry may be accurately solved by an ordinary operator.

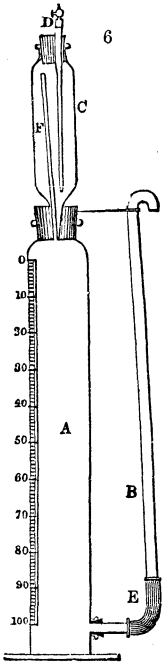
On the same principle, my *Acidimeter* is constructed; pure water of ammonia is made of such a standard strength by an adjusted glass bead, as that 1,000 grain measures of it neutralize exactly a quantity of any one real acid, denoted by its atomic weight, upon either the hydrogen or oxygen scale or radix; as for example, 40 grains of sulphuric acid. Hence it becomes a universal acidimeter; after the neutralization of 10 or 100 grains of any acid, as denoted by the well-defined color in the litmus-tinted ammonia, the test-tube measures of ammonia expended being multiplied by the atomic weight of the acid, the product denotes the quantity of it present in 10 or 100 grains. The proportion of any one free acid in any substance may thus be determined with precision, or to one fiftieth of a grain, in the course of five minutes. Like methods are applied to Chlorometry, and other analytical purposes, with equal facility; adapting the test-liquor to the particular object in view. Instead of using beads for preparing the alkalimetric and acidimetric test-liquors, specific gravity bottles, or hydrometers, may of course be employed; but they furnish incomparably more tedious, and less delicate means of adjustment. To adapt the above methods to the French weights and measures, now used generally also by the German chemists, we need only substitute 100 *deci-grammes* for 100 grains, and proceed in the graduation, &c., as already described.

The possession of two reciprocal test-liquids affords ready and rigid means of verification. For microscopic analyses of alkaline and acid matter, a graduated tube of small bore, mounted in a frame with a valve apparatus at top, so as to let fall drops of any size, and at any interval, is desirable; and such I have employed for many years. Of this kind is my ammonia-meter, used in the ultimate analysis of guanos and other azotized products, in conjunction with a modified apparatus on the principle of that of Varrentrapp and Will. It may be remarked, that when the crude alkali contains some hyposulphite, it should not be calcined with chlorate of potash, because one atom of hyposulphurous acid is thereby converted into two atoms of sulphuric, which of course saturate double the quantity of alkali, previously in combination with the hyposulphurous acid. In such cases it is preferable to change the condition of the sulphurets, sulphites, and hyposulphites, by adding a little neutral chromate of potash to the alkaline solution, whence result sulphate of chromium, water, and sulphur, three bodies, which will not affect the accuracy of the above alkalimetrical process.

In the *Annals of Philosophy* for October, 1817, I described a new instrument for analyzing the earthy and alkaline carbonates, and for determining the quantity of base present in them from the volume of carbonic acid, disengaged by their solution in acids, upon the data of the atomic theory. This method was applied to the analysis of the carbonates of ammonia, soda, potash, lime, magnesian limestone (dolomite), &c.

"The indications of the above analytical instrument are so minute as to enable us, by the help of the old and well-known theorem for computing the proportions of two metals from the specific gravity of an alloy to deduce the proportions of the bases from the volume of gas disengaged by a given weight of a mixed carbonate."*

That small instrument consisted of a bent glass tube, open at one end, and terminated at the other with an egg-shaped bulb from two to three inches in diameter, and it required for operating with it, about five pounds of quicksilver. The following glass apparatus (*fig.* 6) will be found more generally convenient, and equally exact. A is a cylinder, 2 inches in diameter, and 14 inches long. It contains 10,000 grains of water in the graduated portion; 0, or zero being at the top. It has a tubulure in the side close to the bottom, through the cork of which a short tube passes tight, and is connected to a collar of caoutchouc, E, which serves for a joint to the upright tube, B, resting near its open upper end in a hooked wire. Through the cork in the *mouth* of the cylinder, the taper tail of the flask C passes air-tight. The small tube F, open at both ends, is cemented at bottom into the tail of C, and rises to the shoulder of the flask. The cork of C is perforated, and receives air-tight the taper tube D, which can also be closed with the stopcock.



In operating with this apparatus, proceed as follows:—

Fill the cylinder with water, and cover its surface with half an inch of oil. Insert the tail of the flask. Put into the flask C, 58·6 grains of carbonate of potash, or 45·2 of carbonate of soda, according as common pearl-ash or soda-ash is to be tested, along with as much water as will cover fully the lower end of D, and then introduce this tube. Have a bottle containing about 40 parts of oil of vitriol, previously mixed with 60 of water, and cooled. Take of this, in a pouring or dropping glass, 100 water grain measures, and suck this quantity gradually up into the tube D, then shut the stopcock. On opening it slightly the acid will fall into C, and as slowly as may be prudent. The carbonic acid gas, forthwith disengaged, will depress the water in A, cause an overflow of it from the tube B, which, being held in the left hand, must have its swanbeak placed over a basin, and progressively lowered to the level of the descending water in the cylinder. When all the sulphuric acid has been introduced by the right hand, the orifice of D is to be corked, and the tube B continually lowered with the left, till the effervescence being finished, the water in A remains stationary. The number on the centigrade scale, opposite to the surface of the oil, deducting 100 grain measures for the bulk of dilute acid added, denotes the per-centage of pure carbonate of potash, or of soda, in the sample under examination. The above prescribed weights of these two carbonates, when pure, disengage each by the action of sulphuric acid (used here in small excess) 10,000 water grain measures of carbonic acid gas, or 100 measures of the scale on A. The cylinder which I employ contains about 12,000 water grain measures, so that the bottom of the centigrade scale is fully two inches above the level of the lower tubulure. This capacity and the graduation into 120 parts, will be found convenient in certain cases, particularly in analyzing bicarbonates of potash and soda.†

We may estimate 10,000 water grain measures of carbonic acid at 60° Fahr., to weigh 18·4 grains, and we thus perceive what a magnified scale we should possess, if we applied the *vernier* contrivance here, as we do to barometers. At any rate, he must be an awkward operator who can not determine the value of an alkaline carbonate, by the above means, to one part in a thousand.

In operating upon limestones, marles, &c., 42·1 grains should be taken as the standard weight of assay, because that weight of pure carbonate of lime should give out on solution in dilute muriatic acid 10,000 water grain measures of carbonic acid gas. Since 100 water grain measures of liquid hydrochloric acid, specific gravity 1·14, will supersaturate the lime in the above weight of carbonates, that quantity may be used in the experiment. The preceding instrument will be found more convenient in experimenting, as also the system of indication, than one on similar principles constructed by the ingenious Dr. Mohr, of Coblenz.

In examining bicarbonates of potash and of soda, the weights to be used in the above apparatus are 42 grains of the former, and 35¼ grains of the latter, each of which quantities, if the salts be perfect, will disengage 10,000 water grain measures of carbonic acid gas, by the action of sulphuric acid. There will be no harm in taking the formerly prescribed measure of the sulphuric acid though considerably less would answer the purpose. The centigrade measures of gas obtained in A will indicate the carbonated state of the two alkalis respectively. Their alkaline force may be most readily ascertained by my old alkalimeter, with colored test acid. Since the bicarbonates usually sold in our shops, especially that of soda, are far from being exact atomic compounds, they should be always examined, both for their base and acid, which may also be well done in the following way, where the quantity of carbonic acid gas is determined by weight instead of by volume.

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* *Dictionary of Chemistry*, 1821.

† For the greatest precision hot acid may be used in the above experiment, by taking in a graduated test-tube seventy-five grains of water, and filling it up to the line 100 with concentrated sulphuric acid. This mixture being poured in successive portions into the flask C (represented much too large in proportion to the cylinder A), will ensure the expulsion of all the carbonic acid from C, which may be afterward cooled by wrapping round it a towel dipped in cold water.

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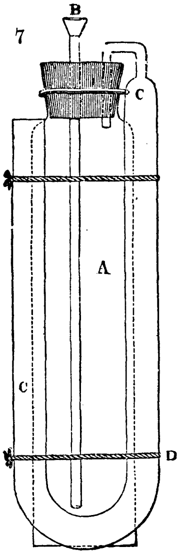

For this purpose, a small compact apparatus of the annexed form (*fig.* 7) will be found convenient; it is to be used in conjunction with my alkalimeter. A in the dotted line is the phial for receiving the carbonate to be tested. B, the funnel into which the test acid is to be poured; C C, an inverted syphon filled with pieces of chloride of calcium for absorbing the aqueous vapors exhaled by the carbonic acid. The loss of weight in the phial above that in the tube of test acid shows the quantity of acid gas, and the indication of the alkalimeter tube, that of alkaline base, from which data the proportion of neutral carbonate and bicarbonate may be immediately deduced. Thus, 100 grains of bicarbonate of soda should give out 51¾ grains of carbonic acid, and saturate 37·6 centigrade measures of the test acid, equivalent to 37·6 grains of real soda. But if neutral carbonate of soda be present, less gas will be given out, and more or less alkali may be indicated, according to the degree of dryness of the neutral soda. The amount of water in the bicarbonate may be determined by igniting 20 grains in a test tube, connected with the chlorcalcium inverted syphon; 10⅓ grains of carbonic acid gas should be expelled, and 2⅛ of water, making a total loss of $12\frac{11}{24}$ grains, of which 2⅛ will be found as water absorbed by the chlorcalcium. But since a very moderate heat suffices to expel the second atom of carbonic acid from the bicarbonate of soda, the readiest mode of estimating its quality is to heat, over a spirit lamp, in a small flask, or retort, connected air-tight by a tube with the mouth of the cylinder A, (*fig.* 6) 70¾ grains of the supposed bicarbonate. Of the perfect salt this quantity should give out pretty exactly 10,000 grain measures of gas; and whatever aliquot part of this volume is evolved will indicate, without calculation, the relative value of the substance as a bisalt. Thus if 8,500 grain measures of gas are obtained, 85 parts of bicarbonate of soda are present in 100. The crystalline form of bicarbonate of potash is a tolerably good criterion of its quality.

The quantity of caustic alkali mixed with carbonate may be readily determined, with sufficient accuracy, by the expert use of my alkalimeter; because, till the caustic portion be nearly neutralized, little or no carbonic gas is expelled. When the effervescence at length begins, the test measures already expended denote the percentage of caustic alkali. It is not right to disregard the alkali which is present in the state of sulphuret, because as such it is effective in many processes of the chemical arts; in the manufacture of yellow soap, crown glass, in the bleaching of linen and cotton goods, &c. The alkalimeter, directly applied, will show the alkali present in this form, when compared with that indicated after ignition of the crude alkali with chlorate of potash, or after its treatment with yellow chromate of potash.*

A few years ago I had the following apparatus made for the ready analysis of carbonates, by ascertaining the loss of weight they suffered from the disengagement of their carbonic acid gas, during their solution in an acid. A, B (*fig.* 8) are two globes, of about two inches in diameter each; A has its inferior neck strangled into a bore nearly capillary; B stands lower, with its centre line on a level with the narrow neck of B. The tubes of these globes are about one half inch in diameter. C is shut at top with a perforated cork, through which enters, air-tight, a small glass tube, which is bent across to the mouth of the tube E, and then passes down into it a little below the centre line of

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* If the alkaline carbonate contains sulphuret, sulphite, or hyposulphite, a teaspoonful of yellow chromate of potash may be added to it, wherefrom result sulphate of chromium, water, and sulphur, which remain in the apparatus without effecting its weight. The mutual action of neutral chromate of potash, and of sulphuret of potash, &c., has been discussed in an ingenious paper published by Dopping, in the *Annalen der Chimie* for May, 1843, p. 172.

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the globe B. This globe is rather more than half filled with sulphuric acid, when the instrument is employed in the analysis of the carbonates. The standard weight of carbonate of soda = $24\frac{1}{8}$ grains, or of carbonate of potash = $31\frac{1}{3}$ grains, is then put into A, having previously laid a minute globe of glass over the lower orifice; the cork, with its small tube, is now firmly adjusted; and the apparatus is weighed in its upright position, either by suspension with a hook to the end of the beam, or by resting it on the scale in a light socket of any kind. It is next laid hold of, and inclined so as to cause a little of the acid in B to pass over into A. Effervescence ensues with greater or less vehemence, according to the nature of the carbonate and quantity of the acid introduced. Should it be too violent, and threaten an overflow by intumescence, it can be instantly abated to any degree by the slightest slope of the instrument. Now, this power of control forms the peculiar feature and advantage of this contrivance; whereas in all other forms of such apparatus that I know, whether by sucking over or pouring in, if a little too much acid comes upon the carbonate, the experiment is effectually marred. The gas disengaged in A must necessarily traverse the sulphuric acid in B, and be stripped of its moisture before escaping into the air. Having supersaturated the alkaline base, and cooled the apparatus, we weigh it again, and the loss of weight in grains and tenths denotes the per-centage of soda or potash, provided their neutral carbonates had been the subjects of experiment. For limestone, on the same plan of computation, $22\frac{3}{4}$ grains may be taken. It deserves to be noted, that the present instrument has only one junction, and needs no chloride of calcium, a substance so apt by its swelling to burst the glass tubes that contain it.*

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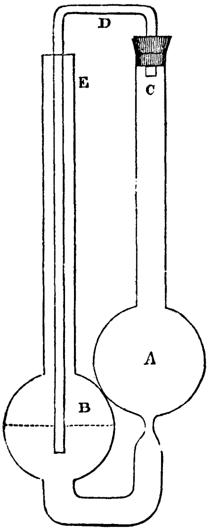

II. ACIDIMETRY.

I have already stated, that water of ammonia of standard strength, faintly tinted with litmus, affords a most exact and convenient acidimeter, when poured or let fall from a graduated dropping-tube. Bicarbonate of potash also, when dissolved in water, so that 1,000 grain measures contain one atom of the salt counted in grains, is a good test-liquor for the same purpose; for if the centigrade measures expended in effecting neutralization are multiplied by the atomic weight of the given acid, the product is the quantity in grains of acid present.

Acidimetry may be likewise exactly performed by measuring in the cylindric gas-meter (*fig.* 6) the volumes of carbonic acid gas disengaged from pure bicarbonate of potash or soda, by a given weight of any acid, taking care to use a small excess of the salt. Thus, for example, 16·8 grains of dry and $20\frac{2}{3}$ of hydrated sulphuric acid disengage 10,000 water grain measures of gas from bicarbonate of potash. Therefore, if $20\frac{2}{3}$ grains of a given sulphuric acid be poured into the flask of *fig.* 6, upon about 50 grains of the bicarbonate, powdered and covered with a little water, it will cause the evolution of a volume of gas proportioned to its strength. If the acid be pure oil of vitriol, that weight of it will disengage 10,000 grain measures of gas; but if it be weaker, so much less gas—the centigrade measures of which will denote the per-centage value of the acid. If the question be put, how much dry acid is present per cent. in a given sulphuric acid, then 16·8 grains of the acid under trial must be used; and the resulting volume of carbonic acid gas read on the scale will denote the per-centage of dry acid.†

For nitric acid, we should take 22·6 grains; for hydrochloric or muriatic acid, 15·34; for acetic acid, 21·6; for citric acid, 24·6; for tartaric acid, 28 grains: then in each case we shall obtain a volume of carbonic acid gas proportioned to the strength and purity of these acids respectively. The nitric, hydrochloric, and acetic acids are referred to in their anhydrous state; the tartaric and citric in their crystalline. If the latter two acids be pure, a solution of 24·6 grains of the first and of 28 of the last

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[*] 1,000 water grain measures of sulphuric acid of specific gravity 1·032, or 32 above water, neutralize 32 grains of soda, and, consequently, one atom, on the hydrogen scale, of each of the other bases, reckoned in grains.

Having in the course of many years subjected my tables of sulphuric, nitric, and muriatic acids, as well as of ammonia, to strict cross-examination, I have found them trustworthy for all alkalimetrical and acidimetrical purposes.

[†] The bicarbonate must be free from carbonate, a point easily secured by washing its powder with cold water, and drying it in the air.

will disengage from 50 grains of bicarbonate of potash 10,000 grain measures of carbonic acid gas.*

Acidimetrical operations may likewise be performed by determining the *weight* of carbonic acid gas expelled from the bicarbonate of potash or soda, by a given quantity of any acid, in the apparatus either *fig.* 7, or *fig.* 8. Here the weights to be taken are as follows, in reference to

	Grains.
Dry Sulphuric acid - - - -	9·127
" Nitric - - - - - -	12·33
" Hydrochloric - - -	8·29
" Acetic - - - - -	11·67
Crystallized Tartaric - - -	13·31
" Citric - - - -	15·13

Each of these quantities of real acid, with 25 or 26 grains of bicarbonate of potash, will give off 10 grains of carbonic acid gas; and hence whatever weight the apparatus loses, being reckoned in grains and tenths of a grain, denotes the per-centage of acid in the sample under trial, without the necessity of any arithmetical reduction. Persons accustomed to the French metrical system may use deci-grammes instead of grains, and they will arrive at the same per-centage results.

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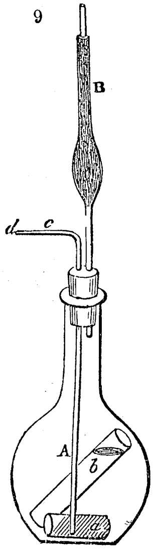

The preceding experiments, in reference to the weight of carbonic acid gas expelled for the purpose of either alkalimetry or acidimetry, may also be made by means of the ordinary apparatus represented in *fig.* 9. A is a small matrass which contains the acid or carbonated alkali at its bottom; and conversely the alkali or acid, for their mutual decomposition in the small test-tube, shown first at *b* nearly upright and filled, but afterward at *a*, horizontal and emptied. B is a bulbous tube filled with fragments of chlorcalcium for absorbing the aqueous vapor that rises with the carbonic acid gas, and *d c* is a small bent tube which dips into the liquid in the matrass. The weighings, &c., may be conducted as already detailed; and when the effervescence is completed, the residuary gas is sucked up through B, while the atmospheric air enters to replace it at the orifice *d* of the bent tube.

The NEW methods which pervade the whole treatise of Drs. Fresenius and Will are all based on the principle of estimating alkalinity, acidity, and the oxygen in manganese (or chlorometry) by the weight of carbonic acid gas evolved. As in taking these measures the gas must be discharged without carrying water off with it, an elegant and ingenious little piece of apparatus has been invented by the authors for effecting that purpose, and it will do it well. A and B (*fig.* 10) are two flasks (wide-mouthed medicine-bottles may be employed). A must have a capacity of from 2 ounces to 2½ ounces of water; it is advisable that B should be somewhat smaller, say of a capacity of about 1 to 1½ ounces. Both flasks are closed by means of doubly perforated corks. These perforations serve for the reception of the tubes *a*, *c*, and *d*. *c* is a tube bent twice at right angles, which enters at its one end just into the flask A, but descends at its other end, near to the bottom of B. These tubes are open at both ends when operating; except the top end *b* of the tube *a*, which is closed by means of a pellet of wax. The substance to be examined is weighed and put into the flask A, into which water is then poured to the extent of one third of its capacity. B is filled with common English sulphuric acid to about half its capacity. Both flasks are then corked (by which they become united by the rectangular tube), and the apparatus is weighed.

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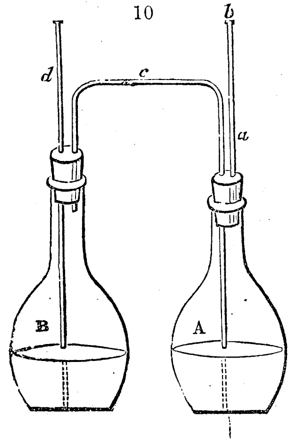

The air of the whole apparatus is next rarefied by applying suction to the tube *d*: the consequence is, that the sulphuric acid contained in B ascends into the tube *c*, and thus a portion of it flows over into B. Immediately upon its coming into contact with the carbonate contained in A, carbonic acid gas is disengaged, and in its escape must necessarily traverse the oil of vitriol in B, and therein deposite all its aqueous vapor before issuing from *d*. The sulphuric acid in passing over into A heats the mixture at the same time, and thus promotes the expulsion of the gas. Whenever this ceases to flow, a little more sulphuric acid must be sent over into A by suction from *d* (or rather from a recurved tube attached, *pro tempore*, to it); an artifice which may be repeated till no more gas can be expelled, even when the contents of A are heated, as they must be at the end by the excess of oil of vitriol.

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* The expulsion of the gas may be completed by surrounding the flask with a towel dipped in hot water.

"From the aperture *b* of the tube *a*, which has been all the time closed, the bit of wax is now to be removed, and to the tube connected with *d*, suction is to be applied, till all the carbonic acid lodged in the apparatus be replaced by atmospheric air. The whole is to be then cooled, wiped, and weighed; the loss of weight indicates exactly the quantity of carbonic acid which existed in the carbonate submitted to experiment. The process is no less neat than it is simple, and does honor to the ingenuity of its inventors. Their mode of deducing the per-centage of alkali from the quantity of carbonic acid discharged in the operation is also quite exact, and suitable for continental chemists familiar with gramme weights and calculations, but certainly not for persons conversant only with ounces, drams, and scruples, or even with grain subdivisions. The whole book, however excellent, needs, for the British public, transposition, before it can serve in this country the purpose intended by its scientific authors. Thus, in section 4, where several results of their analyses are given, the statements have a somewhat mysterious aspect. Should any one ask why the oracular number of 4·83 grammes of carbonate of soda is used as their standard weight for analysis, he can obtain no response in the book, either in a note or anywhere else. A German or French student, familiar with chemical computation, will probably be able to discover that 4·83 grammes of pure carbonate of soda contain, by Berzelius's tables of atomic weights, 2 grammes of carbonic acid; for 53·47 (1 atom of carbonate): 22·15 (1 of carbonic acid) : : 4·83 : 2·00. Such is the simple solution of this apparent enigma, and of some other similar puzzles in the book. Indeed, unless the reader is aware of that proportion, he can not see the grounds of the accordance in the results between experiment and theory, or why the numbers 2·010, 1.993, and 2·020, are presented as specimens of great precision. This accordance gives satisfaction when it is known that these numbers, in experiments 1, 2, and 3, oscillate on one side or other so near to the theoretical number 2·00. But 4 grammes and 83 centi-grammes, as also 1 gramme and 995 milli-grammes, are awkward weights for an ordinary English chemist or apothecary, which would require a month or two's residence in the laboratories of Giessen and Paris to manipulate with readiness.

Again, in testing carbonate of potash, our authors take 6·29 grammes as their unity of weight, undoubtedly, because, if pure, it should discharge, by saturation with the sulphuric acid, 2 grammes of carbonic acid. Here, however, they have not stuck so rigidly as the school of Giessen usually does to Berzelius's atomic numbers; for his atom of carbonate of potash is 69·42; whence, 22·15 : 69·42 : : 2·00 : 6·68, hydrogen = 1·00; or 276·44 : 866·33 : : 2·00 : 6·268 oxygen = 100.

Admitting the value of the new method in testing neutral carbonates, it can not be directly applied to the mixed carbonate and bicarbonate of soda, so commonly sold in this country for bicarbonate; nor is it applicable to the case of a mixture of caustic and carbonated alkali, without the tedious process of previous treatment with carbonate of ammonia and heat.

The new German method of *acidimetry* consists in determining how much carbonic acid gas is disengaged from a standard bicarbonate of soda, by a given weight of any acid. The twin-flask apparatus (*fig.* 10) is used. The weighed portion of acid is put into A, and a sufficient quantity of the soda into a test-tube, which is suspended upright with a silk thread fastened by the pressure of the cork to the mouth of the flask. On letting the thread loose, the test-tube falls, and the cork being instantly replaced, the whole gas evolved is forced to pass through the sulphuric acid in B, and there to deposite its moisture. The experiment is conducted in other respects as already described for alkalimetry.

The following extract from Drs. Fresenius and Will's *New Methods of Alkalimetry*, &c., will show the Giessen plan of calculating results:—

"The amount of anhydrous acid contained in the hydrated acid under examination is determined from the amount of carbonic acid escaped, as follows:—

"Two measures of carbonic acid bear the same proportion to one measure of the anhydrous acid in question, as the amount of carbonic acid expelled does to the amount sought of anhydrous acid. Thus, let us suppose, for instance, we have examined dilute sulphuric acid, and obtained 1·5 grammes of carbonic acid, the arrangement would be:—

$$550\ (2 \times 275) : 501 = 1{\cdot}5 : x$$
$$x = 1{\cdot}36.$$

The amount of sulphuric acid operated upon consequently would contain 1·36 grammes of anhydrous acid. Let us suppose the weight of this amount to have been 15 grammes, the sulphuric acid under examination would contain a per-centage amount of 9·06; for

$$15 : 1{\cdot}36 = 100 : x$$
$$x = 9{\cdot}06.\text{"*}$$

"SECTION XXIX. *Stating the Quantities of the various Acids to be used in their Examination.*—To enable our readers at once, without the trouble of calculation, to determine from the weight of carbonic acid expelled, the exact amount of anhydrous acid contained in those acids which are of most frequent occurrence, we have subjoined lists of certain quantities to be taken of each acid for experiment, so that the number of centi-grammes of carbonic acid expelled will directly indicate the per-centage amount of anhydrous acid in the acid under examination.

"Multiples of those weights may of course be substituted for the numbers given, according to the degree of dilution of the acid under examination. In such cases the number of centi-grammes of the carbonic acid expelled must be divided by the same number, which has served as the multiplier.

"These numbers are obtained by dividing the atomic weight of the acid by 550 (2 × 275, one eq. of carbon),† as follows:—

"Two eq. of carbonic acid, corresponding to one eq. of the acid to be examined, how much should be taken of the latter to expel 1·00 grammes of carbonic acid?

"The arrangement of sulphuric acid, for instance, is as follows:—

$$550 : 501 = 1{\cdot}00 : x$$
$$x = 0{\cdot}91 \text{ (or, more correctly, } 0{\cdot}911).$$

"When examining acids, it is most advisable to use that multiple of the unity (according to the degree of concentration) which will expel from one to two grammes of carbonic acid.

"I. SULPHURIC ACID.

"Unity 0·91 grammes (or, more correctly, 0·911 grammes).

"Multiples:—

2 × 0·911 = 1·822 grammes.
3 × 0·911 = 2·733 "
4 × 0·911 = 3·644 "
5 × 0·911 = 4·555 "
6 × 0·911 = 5·466 "
7 × 0·911 = 6·377 "
8 × 0·911 = 7·288 "
9 × 0·911 = 8·199 "
10 × 0·911 = 9·110 "
15 × 0·911 = 13·665 "
20 × 0·911 = 18·220 "
30 × 0·911 = 27·330 " &c.

"Thus, knowing that 0·91 of anhydrous sulphuric acid will expel 1·00 of carbonic acid, it will be easy to determine what multiple ought to be used, according to the degree of concentration of the acid to be examined."‡

III. CHLOROMETRY,

And the testing of Black Oxide of Manganese for its available Oxygen.

The value of manganese may be estimated very exactly by measuring the quantity of chlorine which a given weight of it produces with hydrochloric acid; the chlorine being at the same time estimated by the quantity of solution of green sulphate of iron, which it will peroxidize. A process of this kind was long ago practised with chloride of lime (bleaching powder or liquor) by Dr. Dalton; and it has been since improved by Mr. Waltercrum. As the conversion of two atoms of green sulphate of iron into red sulphate requires only one atom of oxygen, this change may be effected by the reaction of one atom of chlorine in liberating one atom of oxygen, while this appropriates one of hydrogen from the hydrochloric acid.

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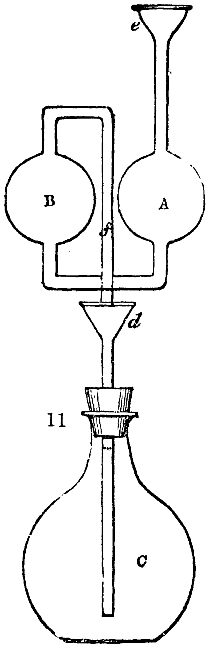
* *New Methods of Alkalimetry, &c.*, pp. 93, 94.

† A typographical error in Mr. Bullock's edition; it should be *carbonic acid.*

‡ *New Methods of Alkalimetry, &c.*, pp. 103–105.

The weight of 2 atoms of green sulphate of iron is 278 = (139 × 2), consisting of atoms of protoxide = 72, × 2 of sulphuric acid = 80, × 14 of water = 126; in all = 278 and this weight is equivalent to 36 of chlorine, to 8 of oxygen, and to 44 of peroxide of manganese.* Therefore, if we take a solution of copperas, containing 278 grains in 1,000 water grain measures, that volume of liquid will represent, by the conversion of its protoxide into peroxide, exactly one atom, either of peroxide of manganese = 44 grains, or 1 atom of chlorine = 36. Hence the following plan of research:—



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Into the flask or phial C of my chlorometric apparatus (*fig.* 11), put 100 grains of the manganese to be tested, and into the globes A, B, pour out of an alkalimetrical tube charged with 1,000 grain measures of the above *equivalent* copperas solution, from 200 to 500 grain measures, according to the supposed quality of the manganese; then introduce through the funnel *d*, some hydrochloric acid of known specific gravity (suppose 1·1), containing nearly 20 per cent. of chlorine, also from a charged alkalimetrical tube, and apply gentle heat to the bottom of the flask by placing it in a capsule of water standing over a spirit-lamp. The chlorine evolved will rise up through the tube *f*, which passes merely beyond the cork, and will enter into the solution in B and A, converting it into red sulphate. Have ready some dry paper imbued with solution of red ferrocyanide of potassium (red prussiate of iron). Dip a slip of whalebone into the liquor in the globe A, through the funnel *e* (represented in the figure rather too high above the globe), and touch the paper with its point. As long as it forms a blue spot, some of the iron still exists as black oxide, and the process is to be urged by the addition of a little more hydrochloric acid to the manganese, as long as chlorine gas continues to be disengaged, and while it maintains the level of the liquor in A above that in B. Whenever the liquor, by the reaction of the chlorine, ceases to stain the test-paper blue, more of the solution from the graduated tube must be added till it begins to do so. By the cautious administration of the hydrochloric acid on the one hand, and of the copperas liquor on the other, the term of saturation will be arrived at in a few minutes. The manganese has then produced all the chlorine which it can yield. The number of water grain measures, of the liquor, or degrees of its alkalimeter scale being multiplied by 44, will give a product denoting the per-centage of pure manganese present in the sample; or being multiplied by 36, a product which will denote the quantity of chlorine by weight which 100 grains of it can serve to generate.

Since one atom of pure manganese (44 grains), in producing 36 grains of chlorine, consumes 2 atoms = 74 grains of hydrochloric acid, the quantity of this acid expended from the graduated tubes, beyond the due proportion of chlorine obtained, will show how much of the acid is unprofitably consumed by foreign substances in the manganese. In fact, every grain of chlorine should, with pyrolusite, be generated by an expenditure of little more than 2 grains of real muriatic acid, or 10 grains weight of the dilute acid, = about 9 grain measures of the graduated tube. Liquid hydrochloric acid of spec. grav. 1·093 contains in 1,000 grain measures exactly 200 grains of real acid. Hence 100 grains of pure pyrosulite should produce about 82 grains of chlorine, and consume about 169 of real muriatic acid = 845 grain measures of liquid acid, spec. grav. 1·093. Instead of taking 100 grains of manganese as the testing dose, 10 or 20 grains may be taken according to the dimensions of the apparatus and the exactness of the operator.

But if it be wished to obtain direct per-centage of *manganese* by the graduated tubes without the trouble of reduction, then for a dose of 10 grains take a solution of fresh green copperas (free from adhering moisture), containing 632 grains in 10,000 grain measures. Proceed as above directed. If the manganese be a pure peroxide, 10 grains of it will generate as much chlorine as will peroxidize exactly 1,000 grain measures, or 100 degrees by the test-tube of the copperas solution. But if the manganese contain only 40 or 50 per cent. of peroxide, then 40 or 50 centigrade measures of the said solution will be equivalent to the chlorine evolved from it by the reaction of hydrochloric acid.

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* Berzelius, in the 4th edition of his *Lehrbuch*, rates the atom of the green sulphate of iron (ferrous sulphate) at 129·43, hydrogen = 1, and considers it, after Mitscherlich, to contain only 6 atoms of water. I have ascertained, by the most careful experiments, that it contains 7 atoms of water; and that 139 grains of it, or 138·44 (Berzelius) are equivalent to 1 atom of chlorbarium, and to very nearly 40 grains of peroxide of iron.

This remarkable error has probably arisen from an attempt to measure the proportion of water in the salt from its loss of weight by desiccation. But I have found it impossible by this means to expel more than 6 atoms of water without causing partial decomposition of the salt by disengagement of sulphuric acid. The copperas so dried acquires such an affinity for water, that it absorbs fully one tenth of its weight of moisture from the atmosphere in the course of an hour.

If the object is on the other hand to obtain direct indications as to *chlorine*, then a test solution of copperas, containing 772 grains in 10,000 grain measures, will serve to show, by the peroxidizement of each 10 grain measures, or of one degree of the centestimal scale of the test-tube, the reaction of one grain of chlorine available for bleaching, &c., in the chloride of lime or of soda, &c. The test solutions of copperas should be kept in well-corked bottles, containing a little powdered sulphuret of iron at their bottom, which is to be shaken up occasionally in order to preserve the iron in the state of protoxide.

The manganese should always be treated with dilute nitric acid before submitting it to the above-described ordeal; and if it exhibits effervescence, 100 grains of it should be digested with the acid for a sufficient time to dissolve out all the carbonates present, then thrown upon a filter, washed and dried before weighing it for the testing operation. The loss of weight thereby sustained denotes the per-centage of carbonates, and if calcareous it will measure the waste of acid that would ensue from that source alone, in using that manganese for the production of chlorine.

That manganese is most *chlorogenous* which contains no carbonates, the least proportion of oxide of iron, and of sesquioxide of manganese.

The plan of testing manganese with oxalic and sulphuric acids was originally practised by M. Berthier and Dr. Thomson, but is lately modified by Drs. Fresenius and Will, who employ oxalate of potash, as likely to afford more exact results. They prescribe a multiple by 3 of 993 milli-grammes = 2·979 grammes, as the quantity of manganese best adapted to experiment; but this quantity will not be found convenient by ordinary British operators.

I, therefore, take leave to prescribe the following proportions: Into the vessel A of my twin-globe apparatus (*fig.* 8), put 100 grains of the ground manganese under trial, along with 250 grains of oxalate of potash and a little water; poise the whole in the scale of a balance; then, by gentle inclination, cause a little of the strong sulphuric acid to pass from B up into A. The oxygen thereby liberated from the manganese, reacting in its nascent state upon the oxalic acid, will convert it into carbonic acid gas; which, in passing through B, will deposite its moisture before escaping into the air. Whenever the extrication of gas ceases, after such a quantity of oil of vitriol has been introduced into the globe A, as both to complete the decomposition of the oxalic acid and to heat the mixture, withdraw the cork for a moment, to replace the carbonic acid with air, then cool, and weigh the apparatus. The loss of weight, in grains, will denote the per-centage value of the manganese; that is, the proportion per cent. of perfect peroxide in the sample. If the manganese be pure no black powder should remain.

The preceding experiment is founded upon the following principle: One atom of peroxide of manganese = 44, contains one atom of oxygen separable by sulphuric acid, and capable of converting one atom of oxalic acid into two atoms of carbonic acid, also = 44, which fly off; and cause therefore a loss of weight equal to that of the whole peroxide. To one atom of oxalic acid, which consists of three atoms of oxygen, and two of carbon—if one atom of oxygen be added, the sum is obviously four atoms of oxygen and two of carbon = 2 atoms of carbonic acid.

The apparatus (*fig.* 10) of Drs. Fresenius and Will, will answer perfectly well for making the same experiment, the manganese being put into A, with about two and a half times its weight of oxalate of potash, and the sulphuric acid being drawn over into the mixture by suction, as above described.

The economy of any sample of manganese in reference to its consumption of acid, in generating a given quantity of chlorine, may be ascertained also by the oxalic acid test: 44 grains of the pure peroxide, with 93 grains of neutral oxalate of potash, and 98 of oil of vitriol disengage 44 grains of carbonic acid, and afford a complete neutral solution; because the one half of the sulphuric acid, = 49 grains, goes to form an atom of sulphate of manganese, and the other half to form an atom of sulphate of potash.

The deficiency in the weight of carbonic acid thrown off will show the deficiency of peroxide of manganese; the quantity of free sulphuric acid may be measured by a test solution of bicarbonate of potash, and the quantity neutralized, compared to the carbonic gas produced, will show, by the ratio of 98 to 44, the amount of acid unprofitably consumed.

In *fig.* 6, the tube, D, may also be graduated, and may contain the quantity of acid, for the purpose either of alkalimetry or acidimetry: and if the lower orifice be capillary, it will allow none of its contents to flow out, till the stopcock in the top orifice is opened.

In *fig.* 7, such a tube as D (*fig.* 6, may be substituted with advantage for the funnel, B; and as that tube, D, may be made of such dimensions as to contain enough of acid to supersaturate the bases of the carbonates in the phial, A, there will be no necessity for a separate vessel to hold the decomposing acid. Thus the apparatus becomes very light, convenient, and may be placed in the small scale of a fine balance; whereas the twin matrasses of Drs. Fresenius and Will (*fig.* 10), as furnished by Mr. Bullock, require a very large pan or scale to stand in. I flatter myself that the instrument, *fig.* 7, so mounted, will be found an acceptable present to practical chemists, and that it will enable them readily to examine, not only carbonates, but also manganese and bleaching substances, with great precision, by the weight of carbonic acid gas disengaged, on the principles above explained.

Into the twin globe apparatus (*fig.* 8), after the sulphuric acid is poured into B, a little water should be poured into C, before the carbonate is introduced into the latter. By this means, the capillary throat of the tube under A will not be apt to get choked with concrete salt.

The following quotations are from the work of Drs. Fresenius and Will, as edited by Mr. Bullock for the English reader. An accurate comparison may thus be made between the relative utility of their methods and mine to the practice of ordinary operators:—

“SECTION XXXIV. *Examination of Manganese: having at the same time due regard to the amount of Acid required for its complete Decomposition.*—We have stated, at Section 30, that it is not a matter of indifference, with regard to the amount of acid employed in the production of chlorine from manganese, what are the minerals which this substance contains in admixture with the peroxide. The following modification of our method will give the most correct information on this point:—

“Sulphuric acid of commerce is taken, and its amount of anhydrous acid determined, as directed at Section 26, or by means of an accurate hydrometer. Of this sulphuric acid as much is weighed into A (*fig.* 10), as to give an amount of 5·47 grammes of anhydrous acid.

“The following table will show the amount which ought to be taken, acoording to the various degree of concentration of the acid:—

Specific weight found.	Per-centage amount of anhydrous acid found.	Amount to be used for the examination.	Specific weight found.	Per-centage amount of anhydrous acid found.	Amount to be used for the examination.
1·8485	81·54	6·708	1·8336	76·65	7·136
1·8480	81·13	6·742	1·8313	76·24	7·174
1·8475	80·72	6·776	1·8290	75·83	7·213
1·8467	80·31	6·811	1·8261	75·42	7·252
1·8460	79·90	6·846	1·8233	75·02	7·291
1·8449	79·49	6·881	1·8206	74·61	7·331
1·8439	79·09	6·916	1·8179	74·20	7·371
1·8424	78·68	6·951	1·8147	73·79	7·412
1·8410	78·28	6·987	1·8115	73·39	7·453
1·8393	77·84	7·027	1·8079	72·97	7·495
1·8376	77·40	7·067	1·8043	72·57	7·537
1·8356	77·02	7·101			

“As much water is then poured into A as will fill the flask to about one fourth; and, lastly, from 6·5 to 7 grammes of neutral oxalate of potash, or from 5·5 to 6 grammes of neutral oxalate of soda, are added; 2·98 grammes of the (finely-pounded) manganese to be examined are then weighed (the manganese must have been previously tested for carbonate alkaline earths: compare this section at the end) into a small glass tube, such as used in acidimetry, and described in Section 25. About the same quantity of pure pyrolusite,[*] in powder, is then put into another similar tube. The tube, with the manganese to be examined, is then suspended in A (*fig.* 10), as described at Section 26, and the apparatus prepared, as directed at Section 3. The

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[*] “Any variety of pyrolusite will serve this purpose, provided it be free from other manganese ores. If it contains heavy spar, it may be employed directly; but should it contain alumina or lime, it must be treated first with dilute nitric acid, at a gentle heat, until all soluble parts have been dissolved; it is then washed and dried. Artificially prepared, hydrated peroxide of manganese may be substituted for pyrolusite.”

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apparatus is then placed on one scale of a balance, together with the other little tube containing the pyrosulite, and exactly weighed.

"The cork of A is then somewhat raised to allow the little tube with the manganese to fall into the flask. The evolution of carbonic acid commences immediately, and continues until all the manganese is decomposed. When the operation begins to get on more slowly, the flask, A, is placed in boiling water, and allowed to remain there until no more bubbles appear. The little wax-stopper is then removed* from *a*, the flask, A, taken out of the hot water, and suction applied to *d*, until the sucked air tastes no longer of carbonic acid. The apparatus, after having been allowed to cool, is wiped dry, and replaced in the original scale, where the little tube with the pyrolusite still remains; weights are then substituted for the loss of carbonic acid. The number of centigrammes required, divided by three, directly indicates the per-centage amount of peroxide of manganese (*vide* Section 32). The centigrammes substituted for the loss of carbonic acid are then removed from the balance, and the little tube with the pyrosulite is thrown into A. (The little wax-stopper must of course previously be replaced on *a*). If no fresh evolution of carbonic acid takes place, the manganese examined consists of pure pyrosulite, and the experiment is at an end. But should a fresh evolution of carbonic acid take place, the operation must be further conducted, and brought to a close, exactly as just stated (*vide suprà*). The apparatus is then replaced on the balance, with an additional weight of three grammes on the same scale. If this is sufficient to restore a perfect equilibrium, no loss of acid has taken place; the manganese, indeed, contains other matters in admixture, but only such as do not consume any acid. But if the scale with the apparatus sinks, this is a certain sign that a portion of the acid has been lost by combining with the oxides which the manganese under examination contains. The number of centigrammes required to restore the perfect equilibrium of the balance, multiplied by 0·6114, immediately indicates how much anhydrous sulphuric acid has been wasted in the decomposition of 100 parts of the manganese under examination. The same number, multiplied by 0·333, indicates the amount of acid wasted in every 100 parts of sulphuric acid employed for the decomposition of the manganese in question. The same number, multiplied by 0·5552, indicate how much anhydrous hydrochloric acid would be wasted in the decomposition of 100 parts of the manganese. The same number, multiplied by 0·333, indicates also how much acid would be wasted in every 100 parts of hydrochloric acid employed for the decomposition of the manganese.

"These figures result from the following equations:—

"I. 275 (eq. of carbonic acid): 501 (eq. of sulphuric acid) = the carbonic acid obtained *minus* (in proportion to the sulphuric acid used) : x.

$$x = \text{this carbonic acid} \times \tfrac{501}{275},\ i.\ e. \times 1{\cdot}822.$$

Thus, the number obtained for x indicates the amount of sulphuric acid corresponding to the amount of carbonic acid obtained *minus*.

"II. 2·98 of manganese: 100 = x of equation I. : x.

$$x = x \text{ of I.} \times \tfrac{100}{298},\ i.\ e. \times 0{\cdot}33557.$$

"The x of the first equation tells us how much sulphuric acid has been wasted without contributing to the decomposition of 2·98 grammes of the manganese; the x of the second equation tells us the same for 100 parts of manganese.

"If, therefore, the amount of carbonic acid obtained *minus* be directly multiplied by the product of the quotients of I. and II.,

1·822 and 0·33557,

i. e. with 0·61141 (the number given above), the amount of anhydrous sulphuric acid wasted in the decomposition of every 100 parts of manganese will immediately be found.

"III. 5·47 (the amount of sulphuric acid used):
100 = the x of I. : x.

$$x = \text{the } x \text{ of I.} \times \tfrac{100}{547},\ i.\ e. \times 0{\cdot}18282.$$

"Of 5·47 of sulphuric acid, the x of I. has been wasted, 100 corresponds to the x of III.

"The x of III. is, therefore, found directly by multiplying the amount of carbonic acid obtained *minus* with the product of the quotients, 1·822 and 0·18282, *i. e.* = 0·33301.

"The figures for hydrochloric acid are found in the same manner (4·967 of hydrochloric acid must be taken instead of 5·47 of the sulphuric acid)."†

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* "This must of necessity be done while the flask is still standing in the hot water, or else the sulphuric acid will recede upon the apparatus being removed from the hot water."

† *New Methods of Alkalimetry, and of determining the Commercial Value of Acids and Manganese.* By Drs. C. R. Fresenius and H Will. Edited by J Lloyd Bullock: pp. 123–128.

ALKANA, is the name of the root and leaves of *Lausania inermis*, which have been long employed in the East, to dye the nails, teeth, hair, garments, &c. The leaves, ground and mixed with a little limewater, serve for dyeing the tails of horses in Persia and Turkey.

ALKANET, the root of. (*Anchusa tinctoria.*) A species of bugloss, cultivated chiefly in the neighborhood of Montpellier. It affords a fine red color to alcohol and oils; but a dirty red to water. Its principal use is for coloring ointments, cheeses, and *pommades*. The spirituous tincture gives to white marble a beautiful deep stain.

ALLIGATION. An arithmetical formula, useful, on many occasions, for ascertaining the proportion of constituents in a mixture, when they have undergone no change of volume by chemical action. When alcoholic liquors are mixed with water, there is a condensation of bulk, which renders that arithmetical rule inapplicable. The same thing holds, in some measure, in the union of metals by fusion. See ALLOY.

ALLOY. (*Alliage*, Fr.; *Legirung*, Germ.) This term formerly signified a compound of gold and silver, with some metal of inferior value, but now means any compound of any two or more metals whatever. Thus, bronze is an alloy of copper and tin; brass, an alloy of copper and zinc; and type metal, an alloy of lead and antimony. All the alloys possess metallic lustre, even when cut or broken to pieces; they are opaque; are excellent conductors of heat and electricity; are frequently susceptible of crystallizing; are more or less ductile, malleable, elastic, and sonorous. An alloy which consists of metals differently fusible is usually malleable in the cold, and brittle when hot, as is exemplified with brass and gong metal.

Many alloys consist of definite or equivalent proportions of the simple component metals, though some alloys seem to form in any proportion, like combinations of salt or sugar with water. It is probable that peculiar properties belong to the equivalent or atomic ratio, as is exemplified in the superior quality of brass made in that proportion.

One metal does not alloy indifferently with every other metal, but it is governed in this respect by peculiar affinities; thus, silver will hardly unite with iron, but it combines readily with gold, copper, and lead. In comparing the alloys with their constituent metals, the following differences may be noted; in general, the ductility of the alloy is less than that of the separate metals, and sometimes in a very remarkable degree; on the contrary, the alloy is usually harder than the mean hardness of its constituents. The mercurial alloys or amalgams are, perhaps, exceptions to this rule.

The specific gravity is rarely the mean between that of each of its constituents, but is sometimes greater and sometimes less, indicating, in the former case, an approximation, and in the latter, a recedure, of the particles from each other in the act of their union. The following tables of binary alloys exhibit this circumstance in experimental detail:—

Alloys having a density greater than the mean of their constituents.

- Gold and zinc
- Gold and tin
- Gold and bismuth
- Gold and antimon
- Gold and cobalt
- Silver and zinc
- Silver and lead
- Silver and tin
- Silver and bismuth
- Silver and antimony
- Copper and zinc
- Copper and tin
- Copper and palladium
- Copper and bismuth
- Lead and antimony
- Platinum and molybdinum
- Palladium and bismuth.

Alloys having a density less than the mean of their constituents.

- Gold and silver
- Gold and iron
- Gold and lead
- Gold and copper
- Gold and iridium
- Gold and nickel
- Silver and copper
- Silver and lead
- Iron and bismuth
- Iron and antimony
- Iron and lead
- Tin and lead
- Tin and palladium
- Tin and antimony
- Nickel and arsenic
- Zinc and antimony.

It would be hardly possible to infer the melting point of an alloy from that of each of its constituent metals; but, in general, the fusibility is increased by mutual affinity in their state of combination. Of this, a remarkable instance is afforded in the fusible metal consisting of 8 parts of bismuth, 5 of lead, and 3 of tin, which melts at the heat of boiling water, or 212° Fahr., though the melting point deduced from the mean of its components should be 514°. This alloy may be rendered still more fusible by adding a very little mercury to it, when it forms an excellent material for certain anatomical injections, and for filling the hollows of carious teeth. Nor do the colors of alloys depend, in any considerable degree, upon those of the separate metals; thus, the color of copper, instead of being rendered paler by a large addition of zinc, is thereby converted into the rich-looking pinchbeck metal.

By means of alloys, we multiply, as it were, the numbers of useful metals, and sometimes give usefulness to such as are separately of little value. Since these compounds can be formed only by fusion, and since many metals are apt to oxydize readily at their melting temperature, proper precautions must be taken in making alloys to prevent this occurrence, which is incompatible with their formation. Thus, in combining tin and lead, rosin or grease is usually put on the surface of the melting metals, the carbon produced by the decomposition of which protects them, in most cases, sufficiently from oxydizement. When we wish to combine tin with iron, as in the tinning of cast-iron tea kettles, we rub sal ammoniac upon the surfaces of the hot metals in contact with each other, and thus exclude the atmospheric oxygen by means of its fumes. When there is a notable difference in the specific gravities of the metals which we wish to combine, we often find great difficulties in obtaining homogeneous alloys; for each metal may tend to assume the level due to its density, as is remarkably exemplified in alloys of gold and silver made without adequate stirring of the melting metals. If the mass be large, and slow of cooling, after it is cast in an upright cylindrical form, the metals sometimes separate, to a certain degree, in the order of their densities. Thus, in casting large bells and cannons with copper alloys, the bottom of the casting is apt to contain too much copper and the top too much tin, unless very dexterous manipulation in mixing the fused materials have been employed immediately before the instant of pouring out the melted mass. When such inequalities are observed, the objects are broken and re-melted, after which they form a much more homogeneous alloy. This artifice of a double melting is often had recourse to, and especially in casting the alloys for the specula of telescopes.

When we wish to alloy three or more metals, we often experience difficulties, either because one of the metals is more oxydable, or denser, or more fusible, than the others, or because there is no direct affinity between two of the metals. In the latter predicament, we shall succeed better by combining the three metals, first in pairs, for example, and then melting the two pairs together. Thus, it is difficult to unite iron with bronze directly; but if, instead of iron, we use tin plate, we shall immediately succeed, and the bronze, in this manner, acquires valuable qualities from the iron. Thus, also, to render brass better adapted for certain purposes, a small quantity of lead ought to be added to it, but this cannot be done directly with advantage: it is better to melt the lead first along with the zinc, and then to add this alloy to the melting copper, or the copper to that alloy, and fuse them together.

We have said that the difference of fusibility was often an obstacle to metallic combination; but this circumstance may also be turned to advantage in decomposing certain alloys by the process called *eliquation*. By this means silver may be separated from copper, if a considerable quantity of lead be first alloyed with the said copper; this alloy is next exposed to a heat just sufficient to melt the lead, which then sweats out, so to speak, from the pores of the copper, and carries along with it the greater part of the silver, for which it has a strong affinity. The lead and the silver are afterwards separated from each other, in virtue of their very different oxydability, by the action of heat and air.

One of the alloys most useful to the arts is brass; it is more ductile and less easily oxydized than even its copper constituent, notwithstanding the opposite nature of the zinc. This alloy may exist in many different proportions, under which it has different names, as tombac, similor, pinchbeck, &c. Copper and tin form, also, a compound of remarkable utility, known under the names of hard brass, for the bushes, steps, and bearings of the axles, arbors, and spindles in machinery; and of bronze, bell-metal, &c. Gold and silver, in their pure state, are too soft and flexible to form either vessels or coins of sufficient strength and durability; but when alloyed with a little copper, they acquire the requisite hardness and stiffness for these and other purposes.

When we have occasion to unite several pieces of the same or of different metals, we employ the process called *soldering*, which consists in fixing together the surfaces by means of an interposed alloy, which must be necessarily more fusible than the metal or metals to be joined. That alloy must also consist of metals which possess a strong affinity for the substances to be soldered together. Hence each metal would seem to require a particular kind of solder, which is, to a certain extent, true. Thus, the solder for gold trinkets and plate is an alloy of gold and silver, or gold and copper; that of silver trinkets, is an alloy of silver and copper; that of copper is either fine tin, for pieces that must not be exposed to the fire, or a brassy alloy called hard solder, of which the zinc forms a considerable proportion. The solder of lead and tinplate is an alloy of lead and tin, and that of tin is the same alloy with a little bismuth. Tinning, gilding, and silvering may also be reckoned a species of alloys, since the tin, gold, and silver are superficially united in these cases to other metals.

Metallic alloys possess usually more tenacity than could be inferred from their con-

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stituents; thus, an alloy of twelve parts of lead with one of zinc has a tenacity double that of zinc. Metallic alloys are much more easily oxydized than the separate metals, a phenomenon which may be ascribed to the increase of affinity for oxygen which results from the tendency of the one of the oxydes to combine with the other. An alloy of tin and lead heated to redness takes fire, and continues to burn for some time like a piece of bad turf.

Every alloy is, in reference to the arts and manufactures, a new metal, on account of its chemical and physical properties. A vast field here remains to be explored. Not above sixty alloys have been studied by the chemists out of many hundred which may be made; and of these very few have yet been practically employed. Very slight modifications often constitute very valuable improvements upon metallic bodies. Thus, the brass most esteemed by turners at the lathe contains from two to three per cent. of lead; but such brass does not work well under the hammer; and, reciprocally, the brass which is best under the hammer is too tough for turning.

That metallic alloys tend to be formed in definite proportions of their constituents is clear from the circumstance that the native gold of the auriferous sands is an alloy with silver, in the ratios of 1 atom of silver united to 4, 5, 6, 12 atoms of gold, but never with a fractional part of an atom. Also, in making an amalgam of 1 part of silver with 12 or 15 of mercury, and afterwards squeezing the mixture through chamois leather, the amalgam separates into 2 parts: one, containing a small proportion of silver and much mercury, passes through the skin; and the other, formed of 1 of silver and 8 of mercury, is a compound in definite proportions, which crystallizes readily, and remains in the knot of the bag. An analogous separation takes place in the tinning of mirrors; for on loading them with the weights, a liquid amalgam of tin is squeezed out, while another amalgam remains in a solid form composed of tin and mercury in uniform atomic proportions. But, as alloys are generally soluble, so to speak, in each other, this definiteness of combination is masked and disappears in most cases.

M. Chaudet has made some experiments on the means of detecting the metals of alloys by the cupelling furnace, and they promise useful applications. The testing depends upon the appearances exhibited by the metals and their alloys when heated on a cupel. Pure tin, when heated this way, fuses, becomes of a grayish black color, fumes a little, exhibits incandescent points on its surface, and leaves an oxyde, which, when withdrawn from the fire, is at first lemon-yellow, but when cold, white. Antimony melts, preserves its brilliancy, fumes, and leaves the vessel colored lemon-yellow when hot, but colorless when cold, except a few spots of a rose tint. Zinc burns brilliantly, forming a cone of oxyde; and the oxyde, much increased in volume, is, when hot, greenish, but when cold, perfectly white. Bismuth fumes, becomes covered with a coat of melted oxyde, part of which sublimes, and the rest enters the pores of the cupel; when cold, the cupel is of a fine yellow color, with spots of a greenish hue. Lead resembles bismuth very much; the cold cupel is of a lemon-yellow color. Copper melts, and becomes covered with a coat of black oxyde; sometimes spots of a rose tint remain on the cupel.

Alloys.—Tin 75, antimony 25, melt, become covered with a coat of black oxyde, have very few incandescent points; when cold, the oxyde is nearly black, in consequence of the action of the antimony: a $\frac{1}{400}$ part of antimony may be ascertained in this way in the alloy. An alloy of antimony, containing tin, leaves oxyde of tin in the cupel: a $\frac{1}{100}$ part of tin may be detected in this way. An alloy of tin and zinc gives an oxyde which, while hot, is of a green tint, and resembles philosophic wool in appearance. An alloy containing 99 tin, 1 zinc, did not present the incandescent points of pure tin, and gave an oxyde of greenish tint when cold. Tin 95, bismuth 5 parts, gave an oxyde of a gray color. Tin and lead give an oxyde of a rusty brown color. An alloy of lead and tin, containing only 1 per cent. of the latter metal, when heated, does not expose a clean surface, like lead, but is covered at times with oxyde of tin. Tin 75, and copper 25, did not melt, gave a black oxyde: if the heat be much elevated, the under part of the oxyde is white, and is oxyde of tin; the upper is black, and comes from the copper The cupel becomes of a rose color. If the tin be impure from iron, the oxyde produced by it is marked with spots of a rust color.

The degree of affinity between metals may be in some measure estimated by the greater or less facility with which, when of different degrees of fusibility or volatility, they unite, or with which they can, after union, be separated by heat. The greater or less tendency to separate into differently proportioned alloys, by long-continued fusion, may also give some information upon the subject. Mr. Hatchett remarked, in his elaborate researches on metallic alloys, that gold made standard with the usual precaul tions, by silver, copper, lead, antimony, &c., and then cast, after long fusion, into verticabars, was by no means a uniform compound; but that the top of the bar, corresponding to the metal at the bottom of the crucible, contained the larger proportion of gold. Hence, for a more thorough combination, two red-hot crucibles should be employed, and the liquefied metals should be alternately poured from the one into the other. To pre vent unnecessary oxidisement from the air, the crucibles should contain, besides the metal, a mixture of common salt and pounded charcoal. The metallic alloy should also be occasionally stirred up with a rod of pottery ware.

The most direct evidence of a chemical change having been effected in alloys is, when the compound melts at a lower temperature than the mean of its ingredients. Iron, which is nearly infusible, acquires almost the fusibility of gold when alloyed with this precious metal. The analogy is here strong with the increase of solubility which salts acquire by mixture, as is exemplified in the difficulty of crystallizing residuums of saline solutions, or mother waters, as they are called.

When there is a strong affinity between the two metals, their alloy is generally denser than the mean, and *vice versâ.* This is exemplified in the alloys of copper with zinc and tin on the one hand; and with copper and lead on the other. When one of the metals is added in excess, there result an atomic compound and an indefinite combination, as would appear from Muschenbroek's experiments. Thus,

1	of lead with	4	of silver give a density of		10·480.
1	do	2		do	11·032.
1	do	3		do	10·831.

The proportion of the constituents is on this principle estimated in France by the *test of the ball* applied to pewter; in which the weight of the alloyed ball is compared with that of a ball of pure tin or standard pewter cast in the same mould. Alloys possess the elasticity belonging to the mean of their constituents, and also the specific caloric.

According to M. Rudberg, while lead solidifies at 325° C., and tin at 228°, and their atomic alloy at 187°, which he calls the fixed point, for a compound $PbSn_3$.

The action of the air is in general less on alloys than on their components; to which, however, there are remarkable exceptions, as for example, with the alloy of 3 parts of lead and 1 of tin, which when heated to redness burns briskly into a red oxide. When two metals, as copper and tin, are combined, which oxidize at different temperatures, they may be separated by fusion with exposure to the air, an artifice practised on the church bells in France to procure tin for making cannon metal bronze. Cupellation of the precious metals is a like phenomenon.

An alloy too slowly cooled is often apt to favor the crystallization of one or more of its components, and thus to render it brittle; and hence an iron mould is preferable to one of sand when there is danger of such a result.

It is not a matter of indifference in what order the metals are melted together in making an alloy. Thus, if we combine 90 parts of tin and 10 of copper, and to this alloy add 10 of antimony; or if we combine 10 parts of antimony with 10 of copper, and add to that alloy 90 parts of tin, we shall have two alloys chemically the same; and still it will be easy to discover that, in other respects, fusibility, tenacity, &c., they totally differ. Whence this result? Obviously from the nature of their combination, dependent upon the order pursued in the preparation, and which continues after the mixture. In the alloys of lead and antimony also, if the heat be raised in combining the two metals together much above their fusing points, the alloy becomes harsh and brittle; probably because some alloy formed at that high temperature is not soluble in the mass.

In common cases the specific gravity affords a good criterion whereby to judge of the proportion of two metals in an alloy. But a very fallacious rule has been given in some respectable works for computing the specific gravity that should result from the alloying of given quantities of two metals of known densities, supposing no chemical condensation or expansion of volume to take place. Thus, it has been taught, that if gold and copper be united in equal weights, the computed specific gravity is merely the arithmetical mean between the numbers denoting the two specific gravities. Whereas the specific gravity of any alloy must be computed by dividing the sum of the two weights by the sum of the two volumes, compared, for convenience sake, to water reckoned unity. Or, in another form, the rule may be stated thus:—Multiply the sum of the weights into the products of the two specific-gravity numbers for a numerator; and multiply each specific gravity-number into the weight of the other body, and add the two products together for a denominator. The quotient obtained by dividing the said numerator by the denominator, is the truly computed mean specific gravity of the alloy. On comparing with that density, the density found by experiment, we shall see whether expansion or condensation of volume has attended the metallic combination. Gold having a specific gravity of 19·36, and copper of 8·87, when they are alloyed in equal weights, give, by the fallacious rule of the arithmetical mean of the densities $\frac{19 \cdot 36 + 8 \cdot 87}{2} = 14 \cdot 11$; whereas the rightly computed mean density is only 12·16. It is evident that, on comparing the first result with experiment, we should be led to infer that there had been a prodigious condensation of volume, though expansion has actually taken place. Let

W, w be the two weights; P, p the two specific gravities, then M, the mean specific gravity, is given by the formula

$$M = \frac{(W+w)\,Pp}{Pw+pW} \therefore 2\,\Delta = -\frac{(P-p)^2}{P+p} = \text{twice}$$

the error of the arithmetical mean; which is therefore always in excess.

Alloys of a somewhat complex character are made by Mr. Alexander Parkes, of Birmingham, of a white or pale color, by melting together 33½ lbs. of foreign zinc, 64 of tin, 1¼ of iron, and 3 of copper; or 50 zinc, 48 tin, 1 iron, and 3 copper; or any intermediate proportion of zinc and copper may be used. The iron and copper are first melted together in a crucible, the tin is next introduced, in such quantities at a time as not to solidify the iron and copper; the zinc is added lastly, and the whole mixed by stirring. The flux recommended for this alloy is 1 part of lime, 1 part of Cumberland (iron?) ore, and 3 parts of sal ammoniac.

Another of his alloys is composed of 66 lbs. of foreign zinc, 33½ tin, 3¼ antimony; or 70¾ zinc, 19½ tin, and 2¾ antimony; or any intermediate proportions, and with or without arsenic. He uses black flux. When to be applied to the sheathing of ships, from 8 to 16 oz. of metallic arsenic are added to every 100 lbs. of alloy. A third class of alloys consists of equal parts of iron and nickel; the copper is next added, and lastly the zinc, or the copper and zinc, may be added as an alloy. 100 lbs. may consist of 45½ lbs. of iron and nickel (*partes æquales*), and 10½ lbs. of foreign zinc; or 30¾ lbs. of alloy of iron and nickel (*p. æ.*), 46 copper, and 26½ zinc; or any intermediate proportions of zinc and copper. He uses also an alloy of 60 lbs. of copper, 20 of zinc, and 20 of silver; or 60 copper, 10 nickel, 10 silver, and 20 zinc; the copper and nickel being first fused together. His fifth alloy is called by him a non-conductor of heat! It is made of 25 nickel, 25 iron, and 50 copper; or 15 nickel, 25 iron, and 60 copper; the last being added after the fusion of the others.

Mr. Parkes also proposes to deposit metals by means of electricity from their iodides, chlorides, and phosphates, while in fusion by heat, either singly or combined with compatible *haloids*.

ALMOND. (*Amande*, Fr.; *Mandel*, Germ.) There are two kinds of almond which do not differ in chemical composition, only that the bitter, by a curious chemical reaction of its constituents, generates in the act of distillation a quantity of a volatile oil, which contains hydrocyanic acid. Vogel obtained from bitter almonds 8·5 per cent. of husks. After pounding the kernels, and heating them to coagulate the albumen, he procured, by expression, 28 parts of an unctuous oil, which did not contain the smallest particle of hydrocyanic acid. The whole of the oil could not be extracted in this way. The expressed mass, treated with boiling water, afforded sugar and gum, and, in consequence of the heat, some of that acid. The sugar constitutes 6·5 per cent. and the gum 3. The vegetable albumen extracted, by means of caustic potash, amounted to 30 parts: the vegetable fibre to only 5. The poisonous aromatic oil, according to Robiquet and Boutron-Charlard, does not exist ready-formed in the bitter almond, but seems to be produced under the influence of ebullition with water. These chemists have shown that bitter almonds deprived of their unctuous oil by the press, when treated first by alcohol, and then by water, afford to neither of these liquids any volatile oil. But alcohol dissolves out a peculiar white crystalline body, without smell, of a sweetish taste at first, and afterwards bitter, to which they gave the name of *amygdaline*. This substance does not seem convertible into volatile oil. See AMYGDALINE.

Sweet almonds, by the analysis of Boullay, consist of 54 parts of the bland almond oil, 6 of uncrystallizable sugar, 3 of gum, 24 of vegetable albumen, 24 of woody fibre, 5 of husks, 3·5 of water, 0·5 of acetic acid including loss. We thus see that sweet almonds contain nearly twice as much oil as bitter almonds do.

ALMOND OIL. A bland fixed oil, obtained usually from bitter almonds by the action of a hydraulic press, either in the cold, or aided by hot iron plates. See OIL.

ALOE. A series of trials has been made within a few years at Paris to ascertain the comparative strength of cables made of hemp and of the aloe from Algiers; and they are said to have all turned to the advantage of the aloe. Of cables of equal size, that made of aloe raised a weight of 2000 kilogrammes (2 tons nearly); that made of hemp, a weight of only 400 kilogrammes. At the exposition of objects of national industry, some years ago, in Brussels, I saw aloe cordage placarded, as being far preferable to hempen; but I believe without just grounds.

ALUDEL. A pear-shaped vessel open at each end, of which a series are joined for distilling mercury in Spain. See MERCURY.

ALUM. (*Alun*, Fr.; *Alaun*, Germ.) A saline body, consisting of the earth of clay, called alumina by the chemists, combined with sulphuric acid and potash, or sulphuric acid and ammonia, into a triple compound. It occurs in the crystallized form of octahedrons, has an acerb subacid taste, and reddens the blue color of litmus or red cabbage.

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Alum works existed many centuries ago at Roccha, formerly called Edessa, in Syria, whence the ancient name of Roch alum given to this salt. It was afterwards made at Foya Nova, near Smyrna, and in the neighborhood of Constantinople. The Genoese, and other trading people of Italy, imported alum from these places into western Europe, for the use of the dyers of red cloth. About the middle of the fifteenth century, alum began to be manufactured at La Tolfa, Viterbo, and Volaterra, in Italy; after which time the importation of oriental alum was prohibited by the pope, as detrimental to the interests of his dominions. The manufacture of this salt was extended to Germany at the beginning of the sixteenth century, and to England at a somewhat later period, by Sir Thomas Chaloner, in the reign of Elizabeth. In its pure state, it does not seem to have been known to the ancients; for Pliny, in speaking of something like plumose alum, says, that it struck a black color with pomegranate juice, which shows that the green vitriol was not separated from it. The *stypteria* of Dioscorides, and the *alumen* of Pliny, comprehended, apparently, a variety of saline substances, of which sulphate of iron, as well as alumina, was probably a constituent part. Pliny, indeed, says, that a substance called in Greek Ὑγρα, or watery, probably from its very soluble nature, which was milk-white, was used for dyeing wool of bright colors. This may have been the mountain butter of the German mineralogists, which is a native sulphate of alumina, of a soft texture, waxy lustre, and unctuous to the touch.

The only alum manufactories now worked in Great Britain, are those of Whitby, in England, and of Hurlett and Campsie, near Glasgow, in Scotland; and these derive the acid and earthy constituents of the salt from a mineral called alum slate. This mineral has a blueish or greenish black color, emits sulphurous fumes when heated, and acquires thereby an aluminous taste. The alum manufactured in Great Britain contains potash as its alkaline constituent; that made in France contains, commonly, ammonia, either alone, or with variable quantities of potash. Alum may in general be examined by water of ammonia, which separates from its watery solutions its earthy basis, in the form of a light flocculent precipitate. If the solution be dilute, this precipitate will float long as an opalescent cloud.

If we dissolve alum in 20 parts of water, and drop this solution slowly into water or caustic ammonia till this be nearly, but not entirely, saturated, a bulky white precipitate will fall down, which, when properly washed with water, is pure aluminous earth or clay, and dried forms 10·82 per cent. of the weight of the alum. If this earth, while still moist, be dissolved in dilute sulphuric acid, it will constitute, when as neutral as possible, the sulphate of alumina, which requires only two parts of cold water for its solution. If we now decompose this solution, by pouring into it water of ammonia, there appears an insoluble white powder, which is subsulphate of alumina, or basic alum; and contains three times as much earth as exists in the neutral sulphate. If, however, we pour into the solution of the neutral sulphate of alumina a solution of sulphate of potash, a white powder will fall if the solutions be concentrated, which is true *alum*; but if the solutions be dilute, by evaporating their mixture, and cooling it, crystals of alum will be obtained.

When newly precipitated alumina is boiled in a solution of alum, a portion of the earth enters into combination with the salt, constituting an insoluble compound, which falls in the form of a white powder. The same combination takes place if we decompose a boiling hot solution of alum with a solution of potash, till the mixture appears nearly neutral by litmus paper. This insoluble or basic alum exists native in the alum-stone of Tolfa, near Civita Vecchia, and it consists in 100 parts of 19·72 parts of sulphate of potash, 61·99 basic sulphate of alumina, and 18·29 water. When this mineral is treated with a due quantity of sulphuric acid, it dissolves, and is converted into the crystallizable alum of commerce.

These experimental facts develop the principles of the manufacture of alum, which is prosecuted under various modifications, for its important uses in the arts. Alum seldom occurs ready-formed in nature; occasionally, as an efflorescence on stones, and in certain mineral waters in the East Indies. The alum of European commerce is fabricated artificially, either from the alum schists or stones, or from clay. The mode of manufacture differs according to the nature of these earthy compounds. Some of them, such as the alum-stone, contain all the elements of the salt, but mixed with other matters from which it must be freed. The schists contain only the elements of two of the constituents, namely, clay and sulphur, which are convertible into sulphate of alumina, and this may be then made into alum by adding the alkaline ingredient. To this class belong the alum-slates, and other analogous schists, containing brown coal.

1. *Manufacture of Alum from the Alum Stone.*—The alum-stone is a rare mineral, being found in moderate quantity at Tolfa, and in larger in Hungary, at Bereghszasz, and Muszag, where it forms entire beds in a hard substance, partly characterized by numerous cavities, containing drusy crystallizations of alum-stone or basic alum. The larger lumps contain more or fewer flints disseminated through them, and are, according to

their quality, either picked out to make alum, or are thrown away. The sorted pieces are roasted or calcined, by which operation apparently the hydrate of alumina, associated with the sulphate of alumina, loses its water, and, as burnt clay, loses its affinity for alum. It becomes, therefore, free; and during the subsequent exposure to the weather the stone gets disintegrated, and the alum becomes soluble in water.

The calcination is performed in common lime-kilns in the ordinary way. In the regulation of the fire it is requisite, here, as with gypsum, to prevent any fusion or running together of the stones, or even any disengagement of sulphuric or sulphurous acids, which would cause a corresponding defalcation in the product of alum. For this reason the contact of the ignited stones with carbonaceous matter ought to be avoided.

The calcined alum-stones, piled in heaps from 2 to 3 feet high, are to be exposed to the weather, and meanwhile they must be continually kept moist by sprinkling them with water. As the water combines with the alum the stones crumble down, and fall, eventually, into a pasty mass, which must be lixiviated with warm water, and allowed to settle in a large cistern. The clear supernatant liquor, being drawn off, must be evaporated, and then crystallized. A second crystallization finishes the process, and furnishes a marketable alum. Thus the Roman alum is made, which is covered with a fine red film of peroxyde of iron.

2. *Alum Manufacture from Alum Schist.*—The greater portion of the alum found in British commerce is made from alum-slate and analogous minerals. This slate contains more or less iron pyrites, mixed with coaly or bituminous matter, which is occasionally so abundant as to render them somewhat combustible. In the strata of brown coal and bituminous wood, where the upper layers lie immediately under clay beds, they consist of the coaly substance rendered impure with clay and pyrites. This triple mixture constitutes the essence of all good alum schists, and it operates spontaneously towards the production of sulphate of alumina. The coal serves to make the texture open, and to allow the air and moisture to penetrate freely, and to change the sulphur and iron present into acid and oxyde. When these schists are exposed to a high temperature in contact with air, the pyrites loses one half of its sulphur, in the form of sublimed sulphur or sulphurous acid, and becomes a black sulphuret of iron, which speedily attracts oxygen, and changes to sulphate of iron, or green vitriol. The brown coal schists contain, commonly, some green vitriol crystals, spontaneously formed in them. The sulphate of iron transfers its acid to the clay, progressively, as the iron, by the action of the air with a little elevation of temperature, becomes peroxydized; whereby sulphate of alumina is produced. A portion of the green vitriol remains, however, undecomposed, and so much the more as there may happen to be less of other salifiable bases present in the clay slate. Should a little magnesia or lime be present, the vitriol gets more completely decomposed, and a portion of Epsom salt and gypsum is produced.

The manufacture of alum from alum schists may be distributed under the six following heads:—1. The preparation of the alum slate. 2. The lixiviation of the slate. 3. The evaporation of the lixivium. 4. The addition of the saline ingredients, or the precipitation of the alum. 5. The washing of the aluminous salts; and, 6. The crystallization.

1. *Preparation of the Alum Slate.*—Some alum slates are of such a nature that, being piled in heaps in the open air, and moistened from time to time, they get spontaneously hot, and by degrees fall into a pulverulent mass, ready to be lixiviated. The greater part, however, require the process of ustulation, from which they derive many advantages. The cohesion of the dense slates is thereby so much impaired that their decomposition becomes more rapid; the decomposition of the pyrites is quickened by the expulsion of a portion of the sulphur; and the ready-formed green vitriol is partly decomposed by the heat, with a transference of its sulphuric acid to the clay, and the production of sulphate of alumina.

Such alum-slates as contain too little bitumen or coal for the roasting process must be interstratified with layers of small coal or brushwood over an extensive surface. At Whitby the alum rock, broken into small pieces, is laid upon a horizontal bed of fuel, composed of brushwood; but at Hurlett small coal is chiefly used for the lower bed. When about four feet of the rock is piled on, fire is set to the bottom in various parts; and whenever the mass is fairly kindled, more rock is placed over the top. At Whitby this piling process is continued till the calcining heap is raised to the height of 90 or 100 feet. The horizontal area is also augmented at the same time till it forms a great bed nearly 200 feet square, having therefore about 100,000 yards of solid measurement. The rapidity of the combustion is tempered by plastering up the crevices with small schist moistened. When such an immense mass is inflamed, the heat is sure to rise too high, and an immense waste of sulphur and sulphuric acid must ensue. This evil has been noticed at the Whitby works. At Hurlett the height to which the heap is piled is only a few feet, while the horizontal area is expanded; which is a much more judicious arrangement. At Whitby 130 tons of calcined schist produce on an average 1 ton of alum.

In this humid climate it would be advisable to pile up on the top of the horizontal strata of brushwood or coal, and schist, a pyramidal mass of schist, which having its surface plastered smooth, with only a few air-holes, will protect the mass from the rains, and at the same time prevent the combustion from becoming too vehement. Should heavy rains supervene, a gutter must be scooped out round the pile for receiving the aluminous lixivium, and conducting it into the reservoir.

It may be observed, that certain alum schists contain abundance of combustible matter, to keep up a suitable calcining heat after the fire is once kindled; and therefore nothing is needed but the first layer of brushwood, which, in this case, may be laid over the first bed of the bituminous schist.

A continual, but very slow heat, with a smothered fire, is most beneficial for the ustulation of alum slate. When the fire is too brisk, the sulphuret of iron may run with the earthy matters into a species of slag, or the sulphur will be dissipated in vapor, by both of which accidents the product of alum will be impaired. Those bituminous alum schists which have been used as fuel under steam boilers have suffered such a violent combustion that their ashes yield almost no alum. Even the best regulated calcining piles are apt to burn too briskly in high winds, and should have their draught-holes carefully stopped under such circumstances. It may be laid down as a general rule, that the slower the combustion the richer the roasted ore will be in sulphate of alumina. When the calcination is complete, the heap diminishes to one half its original bulk; it is covered with a light reddish ash, and is open and porous in the interior, so that the air can circulate freely throughout the mass. To favor this access of air, the masses should not be too lofty; and in dry weather a little water should be occasionally sprinkled on them, which, by dissolving away some of the saline matter, will make the interior more open to the atmosphere.

When the calcined mineral becomes thoroughly cold, we may proceed to the lixiviation. But as, from the first construction of the piles or beds till their complete calcination, many weeks, or even months, may elapse, care ought to be taken to provide a sufficient number or extent of them, so as to have an adequate supply of material for carrying on the lixiviating and crystallizing processes during the course of the year, or at least during the severity of the winter season, when the calcination may be suspended, and the lixiviation becomes unsatisfactory. The beds are known to be sufficiently decomposed by the efflorescence of the salt which appears upon the stones, from the strong aluminous taste of the ashes, and from the appropriate chemical test of lixiviating an aliquot average portion of the mass, and seeing how much alum it will yield to solution of muriate or sulphate of potash.

2. *The Lixiviation.*—The lixiviation is best performed in stone-built cisterns; those of wood, however strong at first, are soon decomposed, and need repairs. They ought to be erected in the neighborhood of the calcining heaps, to save the labor of transport, and so arranged that the solutions from the higher cisterns may spontaneously flow into the lower. In this point of view, a sloping terrace is the best situation for an alum work. In the lowest part of this terrace, and in the neighborhood of the boiling-house, there ought to be two or more large deep tanks, for holding the crude lixivium, and they should be protected from the rain by a proper shed. Upon a somewhat higher level the cisterns of the clear lixivium may be placed. Into the highest range of cisterns the calcined mineral is to be put, taking care to lay the largest lumps at the bottom, and to cover them with lighter ashes. A sufficient quantity of water is now to be run over it, and allowed to rest for some time. The lixivium may then be drawn off, by a stopcock connected with a pipe at the bottom of the cistern, and run into another cistern at a somewhat lower level. Fresh water must now be poured on the partly exhausted schist, and allowed to remain for a sufficient time. This lixivium, being weak, should be run off into a separate tank. In some cases a third addition of fresh water may be requisite, and the weak lixivium which is drawn off may be reserved for a fresh portion of calcined mineral. In order to save evaporation, it is always requisite to strengthen weak leys by employing them instead of water for fresh portions of calcined schist. Upon the ingenious disposition and form of these lixiviating cisterns much of the economy and success of an alum work depend. The hydrometer should be always used to determine the degree of concentration which the solutions acquire.

The lixiviated stone, being thus exhausted of its soluble ingredients, is to be removed from the cisterns, and piled up in a heap in any convenient place, where it may be left either spontaneously to decompose, or, after drying, may be subjected to another calcination.

The density of the solution may be brought, upon an average, up to the sp. gr. of from 1·09 to 1·15. The latter density may always be obtained by pumping up the weaker solutions upon fresh calcined *mine.* This strong liquor is then drawn off, when the sulphate of lime, the oxyde of iron, and the earths are deposited. It is of advantage to leave the liquor exposed for some time, whereby the green vitriol may pass into a per sulphate of iron with the deposition of some oxyde, while the liberated acid may combine with some of the clay present, so as to increase the quantity of sulphate of alumina. The manufacture of alum is the more imperfect, as the quantity of sulphate of iron left undecomposed is greater, and therefore every expedient ought to be tried to convert the sulphate of iron into sulphate of alumina.

3. *The evaporation of the Schist Lixivium.*—As the aluminous liquors, however well settled at first, are apt, on the great scale, to deposite earthy matters in the course of their concentration by heat, they are best evaporated by a surface fire, such as that employed at Hurlett and Campsie. A water-tight stone cistern must be built, having a layer of well rammed clay behind the flags or tiles which line its bottom and sides. This cistern may be 4 or 6 feet wide, 2 or 3 feet deep, and 30 or 40 feet long, and it is covered in by an arch of stone or brickwork. At one extremity of this tunnel, or covered canal, a fire-grate is set, and at the other a lofty chimney is erected. The cistern being filled to the brim with the alum ley, a strong fire is kindled in the reverberatory grate, and the flame and hot air are forced to sweep along the surface of the liquor, so as to keep it in constant ebullition, and to carry off the aqueous parts in vapor. The soot which is condensed in the process falls to the bottom, and leaves the body of the liquor clear. As the concentration goes on, more of the rough lixivium is run in from the settling cistern, placed on a somewhat higher level, till the whole gets charged with a clear liquor of a specific gravity sufficiently high for transferring into the proper lead boilers.

At Whitby, the lead pans are 10 feet long, 4 feet 9 inches wide, 2 feet 2 inches deep at the one end, and 2 feet 8 inches deep at the other. This increase of depth and corresponding slope facilitates the decantation of the concentrated lixivium by means of a syphon, applied at the lower end. The bottom of the pan is supported by a series of parallel iron bars, placed very near each other. In these lead pans the liquor is concentrated, at a brisk boiling heat, by means of the flame of a flue beneath them. Every morning the pans are emptied into a settling cistern of stone or lead. The specific gravity of the liquor should be about 1·4 or 1·5, being a saturated solution of the saline matters present. The proper degree of density must vary, however, with different kinds of lixivia, and according to the different views of the manufacturer. For a liquor which consists of two parts of sulphate of alumina, and one part of sulphate of iron, a specific gravity of 1·25 may be sufficient; but for a solution which contains two parts of sulphate of iron to one of sulphate of alumina, so that the green vitriol must be withdrawn first of all by crystallization, a specific gravity of 1·4 may be requisite.

The construction of an evaporating furnace well adapted to the concentration of aluminous and other crude lixivia, is described under Soda. The liquor basin may be made of tiles or flags puddled in clay, and secured at the seams with a good *hydraulic* cement. A mortar made of quicklime mixed with the exhausted schist in powder, and iron turnings, is said to answer well for this purpose. Sometimes over the reverberatory furnace a flat pan is laid, instead of the arched top, into which the crude liquor is put for neutralization and partial concentration. In Germany, such a pan is made of copper, because iron would waste too fast, and lead would be apt to melt. From this preparation basin the under evaporating trough is gradually supplied with hot liquor. At one side of this lower trough there is sometimes a door, through which the sediment may be raked out as it accumulates upon the bottom. Such a contrivance is convenient for this mode of evaporation, and it permits, also, any repairs to be readily made; but, indeed, an apparatus of this kind, well mounted at first, will serve for many years.

In the course of the final concentration of the liquors, it is customary to add some of the mother waters of a former process, the quantity of which must be regulated by a proper analysis and knowledge of their contents. If these mother waters contain much free sulphuric acid, from the peroxydation of their sulphate of iron, they may prove useful in dissolving a portion of the alumina of the sediment which is always present in greater or less quantity.

4. *The precipitation of the Alum by adding Alkaline Salts.*—As a general rule, it is most advantageous to separate, first of all, from the concentrated clear liquors, the alum in the state of powder or small crystals, by addition of the proper alkaline matter, and to leave the mingled foreign salts, such as the sulphate of iron or magnesia, in solution, instead of trying to abstract these salts by a previous crystallization. In this way we not only simplify and accelerate the manufacture of alum, and leave the mother waters to be worked up at any convenient season, but we also avoid the risk of withdrawing any of the sulphate of alumina with the sulphate of iron or magnesia. On this account, the concentration of the liquor ought not to be pushed so far as that, when it gets cold, it should throw out crystals, but merely to the verge of this point. This density may be determined by suitable experiments.

The clear liquor should now be run off into the precipitation cistern, and have the proper quantity of sulphate or muriate of potash, or impure sulphate or carbonate of ammonia added to it. The sulphate of potash, which is the best precipitant, forms 18·34 parts out of 100 of crystallized alum; and therefore that quantity of it, or its equivalent in muriate of potash, or other potash or ammoniacal salts, must be introduced into the aluminous liquor. Since sulphate of potash takes 10 parts of cold water to dissolve it, but is much more soluble in boiling water, and since the precipitation of alum is more abundant the more concentrated the mingled solutions are, it would be prudent to add the sulphate solution as hot as may be convenient; but, as muriate of potash is fully three times more soluble in cold water, it is to be preferred as a precipitant, when it can be procured at a cheap rate. It has, also, the advantage of decomposing the sulphate of iron present into a muriate, a salt very difficult of crystallization, and, therefore, less apt to contaminate the crystals of alum. The quantity of alkaline salts requisite to precipitate the alum, in a granular powder, from the lixivium, depends on their richness in potash or ammonia, on the one hand, and on the richness of the liquors in sulphate of alumina on the other; and it must be ascertained, for each large quantity of product, by a preliminary experiment in a precipitation glass. Here, an aliquot measure of the aluminous liquor being taken, the liquid precipitant must be added in successive portions, as long as it causes any cloud, when the quantity added will be indicated by the graduation of the vessel. A very exact approximation is not practicable upon the great scale; but, as the mother waters are afterwards mixed together in one cistern, any excess of the precipitant, at one time, is corrected by excess of aluminous sulphate a another, and the resulting alum meal is collected at the bottom. When the precipitated saline powder is thoroughly settled and cooled, the supernatant mother water must be drawn off by a pump, or rather a syphon or stopcock, into a lower cistern. The more completely this drainage is effected, the more easily and completely will the alum be purified.

This mother liquor has, generally, a specific gravity of 1·4 at a medium temperature of the atmosphere, and consists of a saturated solution of sulphate or muriate of black and red oxyde of iron, with sulphate of magnesia, in certain localities, and muriate of soda, when the soaper's salt has been used as a precipitant, as also a saturated solution of sulphate of alumina. By adding some of it, from time to time, to the fresh lixivia, a portion of that sulphate is converted into alum; but, eventually, the mother water must be evaporated, so as to obtain from it a crop of ferruginous crystals; after which it becomes capable, once more, of giving up its alum to the alkaline precipitants.

When the aluminous lixivia contain a great deal of sulphate of iron, it may be good policy to withdraw a portion of it by crystallization before precipitating the alum. With this view, the liquors must be evaporated to the density of 1·4, and then run off into crystallizing stone cisterns. After the green vitriol has concreted, the liquor should be pumped back into the evaporating pan, and again brought to the density of 1·4. On adding to it, now, the alkaline precipitants, the alum will fall down from this concentrated solution, in a very minute crystalline powder, very easy to wash and purify. But this method requires more vessels and manipulation than the preceding, and should only be had recourse to from necessity; since it compels us to carry on the manufacture of both the valuable alum and the lower priced salts at the same time; moreover, the copperas extracted at first from the schist liquors carries with it, as we have said, a portion of the sulphate of alumina, and acquires thereby a dull aspect; whereas the copperas obtained after the separation of the alum is of a brilliant appearance.

5. *The washing, or edulcoration, of the Alum Powder.*—This crystalline pulverulent matter has a brownish color, from the admixture of the ferruginous liquors; but it may be freed from it by washing with very cold water, which dissolves not more than one sixteenth of its weight of alum. After stirring the powder and the water well together, the former must be allowed to settle, and then the washing must be drawn off. A second washing will render the alum nearly pure. The less water is employed, and the more effectually it is drained off, the more complete is the process. The second water may be used in the first washing of another portion of alum powder, in the place of pure water. These washings may be added to the schist lixivia.

6. *The crystallization.*—The washed alum is put into a lead pan, with just enough water to dissolve it at a boiling heat; fire is applied, and the solution is promoted by stirring. Whenever it is dissolved in a saturated state, it is run off into the crystallizing vessels, which are called *roching* casks. These casks are about five feet high, three feet wide in the middle, somewhat narrower at the ends; they are made of very strong staves, nicely fitted to each other, and held together by strong iron hoops, which are driven on *pro tempore*, so that they may be easily knocked off again, in order to take the staves asunder. The concentrated solution, during its slow cooling in these close vessels, forms large regular crystals, which hang down from the top, and project from the sides, while a thick layer or cake lines the whole interior of the cask. At the end of eight or ten days

more or less, acccording to the weather, the hoops and staves are removed, when a cask of apparently solid alum is disclosed to view. The workman now pierces this mass with a pickaxe at the side near the bottom, and allows the mother water of the interior to run off on the sloping stone floor into a proper cistern, whence it is taken and added to another quantity of washed powder to be crystallized with it. The alum is next broken into lumps, exposed in a proper place to dry, and is then put into the finished bing for the market. There is sometimes a little insoluble basic alum (subsulphate) left at the bottom of the cask. This being mixed with the former mother liquors, gets sulphuric acid from them; or, being mixed with a little sulphuric acid, it is equally converted into alum.

When, instead of potash or its salts, the ammoniacal salts are used, or putrid urine, with the aluminous lixivia, ammoniacal alum is produced, which is perfectly similar to the potash alum in its appearance and properties. At a gentle heat both lose their water of crystallization, amounting to 45½ per cent. for the potash alum, and 48 for the ammoniacal. The quantity of acid is the same in both, as, also, very nearly the quantity of alumina, as the following analyses will show:—

Potash alum.		Ammonia alum.	
Sulphate of potash	18·34	Sulphate of ammonia	12·88
Sulphate of alumina	36·20	Sulphate of alumina	38·64
Water	45·46	Water	48·48
	100·00		100·00

Or otherwise, Potash alum.		Ammonia alum.	
1 atom sulphate of potash	1089·07	1 atom sulphate of ammonia	716·7
1 alumina	2149·80	1 alumina	2149·8
24 water	2669·52	24 water	2699·5
	5938·39		5566·0

Or, Potash alum.		Ammonia alum.	
Alumina	10·82	Alumina	11·90
Potash	9·94	Ammonia	3·89
Sulphuric acid	33·77	Sulphuric acid	36·10
Water	45·47	Water	48·11
	100·00		100·00

When heated pretty strongly, the ammoniacal alum loses its sulphuric acid and ammonia, and only the earth remains. This is a very convenient process for procuring pure alumina. Ammoniacal alum is easily distinguished from the other by the smell of ammonia which it exhales when triturated with quicklime. The Roman alum, made from alum-stone, possesses most of the properties of the schist-made alums, but it has a few peculiar characters: it crystallizes always in opaque cubes, whereas the common alum crystallizes in transparent octahedrons. It is probable that Roman alum is a sulphate of alumina and potash, with a slight excess of the earthly ingredient. It is permanent when dissolved in cold water; for after a slow evaporation it is recovered in a cubical form. But when it is dissolved in water heated to 110° Fahr. and upwards, or when its solution is heated above this pitch, subsulphate of alumina falls, and on evaporation octahedral crystals of common alum are obtained. The exact composition of the Roman alum has not been determined, as far as I know. It probably differs from the other also in its water of crystallization. The Roman alum contains, according to MM. Thenard and Roard, only $\frac{1}{2200}$ of sulphate of iron, while the common commercial alums contain $\frac{1}{1000}$. It may be easily purified by solution, granulation, crystallization, and washing, as has been already explained.

Alum is made extensively in France from an artificial sulphate of alumina. For this purpose clays are chosen as free as possible from carbonate of lime and oxyde of iron. They are calcined in a reverberatory furnace, in order to expel the water, to peroxydize the iron, and to render the alumina more easily acted on by the acid. The expulsion of the water renders the clay porous and capable of absorbing the sulphuric acid by capillary attraction. The peroxydation of the iron renders it less soluble in the sulphuric acid; and the silica of the clay, by reacting on the alumina, impairs its aggregation, and makes it more readily attracted by the acid. The clay should, therefore, be moderately calcined; but not so as to indurate it like pottery ware, for it would then suffer a species of silicious combination which would make it resist the action of acids. The clay is usually calcined in a reverberatory furnace, the flame of which serves thereafter to heat two evaporating pans and a basin for containing a mixture of the calcined clay and sulphuric acid. As soon as the clay has become friable in the furnace it is taken out, reduced to powder, and passed through a fine sieve. With 100 parts of the pulverized clay, 45 parts of sulphuric acid, of sp. gr. 1·45, are well mixed, in a stone basin, arched over with brickwork. The flame and hot air of a reverberatory furnace are made to play along the mixture, in the same way as described for evaporating the schist liquors. See Soda. The mixture, being stirred from time to time, is, at the end of a few days, to be raked out, and to be set aside in a warm place, for the acid to work on the clay, during six or eight weeks. At the end of this time it must be washed, to extract the sulphate of alumina. With this view, it may be treated like the roasted alum ores above described. If potash alum is to be formed, this sulphate of alumina is evaporated to the specific gravity of 1·38; but if ammonia alum, to the specific gravity of only 1·24; because the sulphate of ammonia, being soluble in twice its weight of water, will cause a precipitation of pulverulent alum from a weaker solution of sulphate of alumina than the less soluble sulphate of potash could do.

The alum stone, from which the Roman alum is made, contains potash. The following analysis of *alunite*, by M. Cordier, places this fact in a clear light:—

Sulphate of potash - - - -	18·53
Sulphate of alumina - - - -	38·50
Hydrate of alumina - - - -	42·97
	100·00

To transform this compound into alum, it is merely necessary to abstract the hydrate of alumina. The ordinary alum stone, however, is rarely so pure as the above analysis would seem to show; for it contains a mixture of other substances; and the above are in different proportions.

Alum is very extensively employed in the arts, most particularly in dyeing, lake making, dressing sheep-skins, pasting paper, in clarifying liquors, &c. Its purity for the dyer may be tested by prussiate of potash, which will give solution of alum a blue tint in a few minutes if it contain even a very minute portion of iron. A bit of nut-gall is also a good test of iron.

Alum liquors.—In the alum works on the Yorkshire coast, 8 different liquors are met with.

1st. "Raw Liquor." The calcined alum shale is steeped in water till the liquor has acquired a specific gravity of 9 or 10 pennyweights, according to the language of the alum-maker.

2d. "Clarified Liquor." The raw liquor is brought to the boiling point in lead pans, and suffered to stand in a cistern till it has cleared: it is then called clarified liquor. Its gravity is raised to 10 or 11 pennyweights.

3d. "Concentrated Liquor." Clarified liquor is boiled down to about 20 pennyweights. This is kept merely as a test of the comparative value of the potash salts used by the alum-maker.

4th. "Alum Mother Liquor." The alum pans are fed with clarified liquor, which is boiled down to about 25 or 30 pennyweights, when a proper quantity of potash salt in solution is mixed with it, and the whole run into coolers to crystallize. The liquor pumped from those rough crystals is called "alum mothers."

5th. "Salts Mothers." The alum mothers are boiled down to a crystallizing point, and afford a crop of "Rough Epsom," which is a sulphate of magnesia and protoxide of iron.

6th and 7th. "Alum Washings." The rough crystals of Alum (No. 4) are washed twice in water, the first washing being about 4 pennyweights, the second about 2½, the difference in gravity being due to mother liquor clinging to the crystals.

8th. "Tun Liquor." The washed crystals are now dissolved in boiling water, and run into the "roching tuns" (wood vessels lined with lead) to crystallize. The mother liquor of the "roch alum" is called "tun liquor;" it is, of course, not quite so pure as a solution of roch alum in water.

The alum-maker's sp. gr. bottle holds 80 pennyweights of water, and by 10 penny weights he means 10 more than water, or 90.

The numbers on Twaddle's hydrometer, divided by 2·5, give alum-makers' pennyweights.

The alum maker tests his samples of potash salts comparatively by dissolving equal weights of the different samples in equal measures of alum liquor at 20 pennyweights, heated up to the boiling-point, and weighing the quantity of alum crystals produced on cooling.

For the above information I am indebted to my friend, Mr. Maurice Scanlan, who superintended for some time the Mulgrave alum works.

He informs me that 61½ tons of the alum rock at the Mulgrave Works, to the north of Whitby, yield, after calcination, &c., one ton of alum.

It has been computed that with sulphur at 6*l.* per ton, sulphuric acid of sp. gr., 1·750 can be produced at 3*l.* per ton, including the mere cost of making: this acid contains 2 atoms of water: 174 tons of this acid, and 87¼ tons of sulphate of potash, with the pipe-clay, will form 474 tons of alum; so that the nett cost would be 522*l.* for the acid + 1047*l.* for the sulphate of potash, = 1569*l.*; which sum divided by 474, gives a quotient of 3*l.* 6*s.* for the nett cost of 1 ton of alum by the direct process.

At the pit 1 ton of alum—rock or mine, costs 3*l.* 4*s.*; to which, adding the cost of the potash salt for 1 ton of alum, 3*l.* 15*s.*, they constitute together an amount of 6*l.* 19*s.* From the latter sum 1*l.* 10*s.* must, however, be deducted for the value of rough Epsom salt produced, leaving a balance of 5*l.* 9*s.* for the cost of a ton of mine-alum, prior to evaporation and crystallization.

A patent was obtained in November, 1839, by Mr. William Wiesman, of Duesburg, for improvements in the manufacture of alum. He subjects potter's clay to a moderate red heat, grinds it, and subjects the powder, in leaden pans, to the action of concentrated sulphuric acid (76° Beaumé), taking care to use excess of clay and a moderate heat. This mixture is to be stirred till it is dry, then treated with boiling water, in order to dissolve the sulphate of alumina formed. So far the process is old and well known. The novelty consists in freeing the saline solution from iron by ferrocyanure of potassium (prussiate of potash). When the iron has been all thrown down in the form of prussian blue, the liquor is allowed to settle, the supernatant pure sulphate is drawn off, and evaporated till it forms on cooling a concrete mass, which may be moulded into the shape of bricks, &c., for the convenience of packing.

Alum, manufacture of.—The manufacture of alum from clay and clay slate, or shale, is now beginning to assume a considerable aspect in the list of our manufactures, and several improvements in this way have lately been patented, which promise to extend largely this branch of industry. One in particular, for the fabrication of alum from the ash or residue left after the combustion of a kind of coal, called Boghead coal, seems based on the sound principle of industrial economy which turns every waste product to profitable account. It was but the other day that this very Boghead ash was a serious impediment to the sale of the coal, and perceptibly diminished its price in the market. Now, however, it constitutes a decided item of value, and powerfully vindicates the right of chemistry to the title of a useful and profitable science. In preparing alum from clay or shale, it is of infinite importance that so much and no more heat be applied to the clay or shale, in the first instance, as will just expel the water of combination, without inducing contraction. A temperature of 600° Fahr. is well adapted to effect this object, provided it be maintained for a sufficient period. When this has been carefully done, the silicate of alumina remaining is easily enough acted upon by sulphuric acid, either slightly diluted or of the ordinary commercial strength. The best form of apparatus is a leaden boiler, divided into two parts by a perforated septum or partition, also in lead—though on a very large scale, brickwork set in clay might be employed. Into one of the compartments the roasted clay or shale should be put, and diluted sulphuric acid being added, the bottom of the other compartment may be exposed to the action of a well-regulated fire, or—what is better—heated by means of steam through the agency of a coil of leaden pipe. In this way a circulation of the fluid takes place throughout the mass of shale; and, as the alumina dissolves, the dense fluid it produces, falling continually towards the bottom of the boiler, is replaced by dilute acid, which, becoming in its turn saturated, falls like the first; and so on in succession, until either the whole of the alumina is taken up, or the acid in great part neutralized. The solution of sulphate of alumina, thus obtained, is sometimes evaporated to dryness, and sold under the name "concentrated alum;" but more generally it is boiled down until of the specific gravity of about 1·35, then one or other of the carbonates, muriate, or sulphates of potash or ammonia, or a mixture of these, is added to the boiling fluid; and as soon as the solution is complete, the whole is run out into a cooler to crystallize. The rough alum thus made is sometimes purified by a subsequent recrystallization, after which it is "roched" for the market—a process intended merely to give it the ordinary commercial aspect, but of no real value in a chemical point of view. Alum not unfrequently contains iron, an impurity which unfits it for many uses in the arts, and more especially for the purposes of the dyer. The best mode of

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ascertaining the presence of this impurity, and demonstrating its amount, is that previously stated in the commencement of this article,—that is, mix a solution of the suspected alum with tartaric acid, or an alkaline tartrate, and then add an excess of carbonate of soda; after which, pour in a few drops of hydrosulphate of ammonia, when, if iron be present, a black precipitate will ensue. If the alum contains lime or magnesia, then the addition of carbonate of soda causes a white precipitate, which must be removed by filtration before applying the hydrosulphate of ammonia.

Alum manufacture simplified.—The alum shale, or schist, is the material whence the alum is obtained: this shale is roasted in heaps, in the open air, in order to render it porous, and more absorbent of the sulphuric acid. To the roasted shale, sulphuric acid of sp. gr. 1·75 is added, by which means sulphate of alumina is formed. In order to wash out from the almost dry mass this sulphate of alumina, and at the same time to supply the equivalent of the sulphate of ammonia necessary to constitute the formation of the double salt of alumina and ammonia, the boiling hot mother liquor of a previous operation is employed; and, as this mother liquor, when removed from the alum crystallizers, contains free sulphuric acid, the ammonia from a still, containing the ammoniacal liquor of the gas works, is distilled into it, and the boiling hot solution of sulphate of ammonia thus formed dissolves out the sulphate of alumina from the shale. The alum liquor thus obtained is of such a specific gravity, that it crystallizes without the necessity of having recourse to evaporation, and thus a considerable saving in fuel is effected. In order to obtain ammoniacal salts, such as sulphate and muriate, with the greatest possible economy, a series of two or more—say, for instance, four—cylindrical boilers are employed, each of which is placed at such a distance above the other, that the contents of the upper boiler may be drawn off into the one next below it. The uppermost boiler is provided with an exit pipe, and has also a supply pipe, connecting the boiler with a reservoir of ammoniacal gas liquor. Into the lowermost vessel of the series passes a pipe conveying high pressure steam, by means of which the liquor in the boiler soon becomes heated to the boiling point. The vapor of ammonia and water pass off through an exit pipe into the boiler placed next above it in the series, the liquor in which also quickly boils, and vapor of ammonia and water pass off in the same way as before to the next vessel above it, and so throughout the series. By the time the vapor of ammonia passes off from the uppermost boiler, it has been so concentrated that, on passing it into sulphuric or muriatic acid, a concentrated solution of either of those salts is obtained, of sufficient sp. gr. to crystallize without evaporation, and thus a considerable saving in fuel and time is effected, and the ammoniacal liquor most thoroughly exhausted. Fresh supplies of ammoniacal liquor are constantly furnished to the uppermost vessel from the reservoir; the partially exhausted liquors are run from the higher to the lower vessels in succession, and the exhausted liquors run off to waste, from time to time, from the lowermost vessel of the series.

ALUMINA. The pure earth of clay, or argillaceous earth. It is the oxide of the metal aluminum, the basis of the aluminous salts, and the principal constituent of porcelain, pottery, bricks and tiles.

AMADOU. The French name of the spongy combustible substance called in German *zundersehwamm*, prepared from a species of agaric, the *boletus igniarius*, a kind of mushroom which grows on the trunks of old oaks, ashes, beeches, &c. It must be plucked in the months of August and September. It is prepared by removing the outer bark with a knife, and separating carefully the spongy substance of a yellow brown color, which lies within it, from the ligneous matter below. This substance is cut into thin slices, and beat with a mallet to soften it, till it can be easily pulled asunder between the fingers. In this state the *boletus* is a valuable substance for stopping oozing hemorrhages, and some other surgical purposes. To convert it into tinder it must receive a finishing preparation, which consists in boiling it in a strong solution of nitre; drying it, and beating it anew, and putting it a second time into the solution. Sometimes, indeed, to render it very inflammable, it is imbued with gunpowder, whence the distinction of black and brown amadou.

All the puff balls of the lycopodium genus of plants, which have a fleshy or filamentous structure, yield a tinder quite ready for soaking in gunpowder water. The Hindoos employ a leguminous plant, which they call *solu*, for the same purpose. Its thick spongy stem, being reduced to charcoal, takes fire like amadou.

AMALGAM. When mercury is alloyed with any metal, the compound is called an amalgam of that metal; as, for example, an amalgam of tin, bismuth, &c.

AMALGAMATION. This is a process used extensively in extracting silver and gold from certain of their ores, founded on the property which mercury has to dissolve these metals as disseminated in the minerals, and thus to separate them from the earthy matters. See MERCURY, METALLURGY, and SILVER.

AMBER. (*Succin*, Fr.; *Bernstein*, Germ.) A mineral solid, of a yellow colour of various shades, which burns quite away with flame, and consists of carbon, hydrogen, and oxygen, in nearly the same proportions, and the same state of combination, as vegetable resin. Its specific gravity varies, by my trials, from 1·080 to 1·085. It becomes negatively and powerfully electrical by friction. When applied to a lighted candle it takes fire, swells considerably, and exhales a white smoke of a pungent odor; but does not run into drops. Copal, which resembles it in several respects, differs in being softer, and in melting into drops at the flame; and mellite, or honey-stone, which is a mineral of a similar color, becomes white when laid on a red-hot coal.

The texture of amber is resino-vitreous, its fracture conchoidal, and lustre glassy. It is perfectly homogeneous; sufficiently hard to scratch gypsum, and to take a fine polish. It is, however, scratched by calcareous spar. When amber is distilled in a retort, crystalline needles of succinic acid sublime into the dome, and oil of amber drops from the beak into the receiver. Fossil resins, such as that of Highgate, found in the London clay formation, do not afford succinic acid by heat: nor does copal. Amber is occasionally found of a whitish and brownish color.

The most interesting fact relative to this vegeto-mineral is its geological position, which is very characteristic and well determined. It is found almost uniformly in separate nodules, disseminated in the sand, clay, or fragments of lignite of the plastic clay, and lignite formation, situated between the *calcaire grossier* (crag limestone) of the tertiary strata above, and the white chalk below. The size of these nodules varies from a nut to a man's head; but this magnitude is very rare in true amber. It does not occur either in continuous beds, like the chalk flints, nor in veins; but it lies at one time in the earthy or friable strata, which accompany or include the lignites; at another, entangled in the lignites themselves; and is associated with the minerals which constitute this formation, principally the pyrites, the most abundant of all. The pieces of amber found in the sands, and other formations evidently alluvial, those met with on the sea-coasts of certain countries, and especially Pomerania, come undoubtedly from the above geological formation; for the organic matters found still adhering to the amber leave no doubt as to its primitive place. Amber does not, therefore, belong to any postdiluvian or modern soil, since its native bed is covered by three or four series of strata, often of considerable thickness, and well characterized; proceeding upwards from the plastic clay which includes the amber: these are, the crag limestone, the bone gypsum, with its marls, the marly limestone, the upper marl sandstone, which covers it, and, lastly, the fresh water or lacustrine formation, often so thick, and composed of calcareous and silicious rocks.

The amber bed is not, however, always covered with all these strata; and it is ever rare to see a great mass of one of them above the ground which contains it; because, were it buried under such strata, it would be difficult to meet with such circumstances as would lay it spontaneously open to the day. But by comparing observations made in different places, relatively to the patches of these formations, which cover the amber deposites, we find that no other mineral formations have been ever seen among them except those above detailed, and thus learn that its geological locality is completely determined.

The proper yellow amber therefore, or the Borussic, from the country where it has been most abundantly found, belongs to the plastic clay formation, intermediate, in England, between the chalk and the London clay. It is sometimes interposed in thin plates between the layers of the lignites, but more towards the bark of the fibrous lignites, which retain the form of the wood, than towards the middle of the trunk of the tree; a position analogous to that of the resinous matters in our existing ligneous vegetables. The fibrous lignites which thus contain amber belong to the dicotyledinous woods. Hence that substance seems to have been formed during the life of the vegetable upon which it is now incrusted. It must be remembered that the grounds containing the amber are often replete with the sulphates of iron, alumina, and lime, or at least with the pyritous elements of these salts. Some specimens of amber have a surface figured with irregular meshes, indicating a sort of shrinkage from consolidation, and consequently a matter that was at one time fluid, viscid, or merely soft. From optical examination, Dr. Brewster has concluded amber to be of vegetable origin.

The different bodies included in the amber, distinguishable from its transparence, demonstrate, indeed, in the most convincing manner, its primitive state of liquidity or softness. These bodies have long exercised the skill of naturalists. They are generally insects, or remains of insects, and sometimes leaves, stalks, or other portions of vegetables. Certain families of insects occur more abundantly than others. Thus the *hymenoptera*, or insects with four naked membranaceous wings, as the bee and wasp, and the *diptera*, or insects with two wings, as gnats, flies, gadflies, &c.; then come the spider tribe; some *coleoptera* (insects with crustaceous shells or elytra, which shut together, and form a longitudinal suture down the back), or beetles, principally those which live on trees; such as the *elaterides*, or leapers, and the *chrysomelida*. The lepidoptera, or insects with

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four membranaceous wings, and pterigostea covered with mail-like scales, are very rare in amber. We perceive from this enumeration, which results from the labors of Germar, Schweiger, &c., that the insects enveloped in this resinous matter are in general such as sit on the trunks of trees, or live in the fissures of their bark. Hitherto, it has not been found possible to refer them to any living species; but it has been observed in general that they resemble more the insects of hot climates than those of the temperate zones.

The districts where amber occurs in a condition fit for mining operations are not numerous; but those in which it is met with in small scattered bits are very abundant. Its principal exploitation is in Eastern Prussia, on the coasts of the Baltic Sea, from Memel to Dantzick, particularly in the neighborhood of Konigsberg, along the shore which runs north and south from Grossdirschheim to Pillau, and in several other places near Dantzick.

It is collected upon this coast in several ways; 1. In the beds of small streams which run near the villages, and in rounded fragments without bark, or in the sand-banks of rivers, in pieces thrown back by the sea, and rounded by the waves. 2. If the pieces thrown up by the waters are not numerous, the fishers, clothed in a leather dress, wade into the sea up to the neck, seek to discover the amber by looking along its surface, and seize it with bag nets, hung at the end of very long poles. They conclude that a great deal of amber has been detached from the cliffs by the sea, when many pieces of lignite (wood coal) are seen afloat. This mode of collecting amber is not free from danger, and the fishers, therefore, advance in troops, to lend each other aid in case of accident; but their success, even thus, is most precarious. 3. The third method of searching for amber is a real mining operation: it consists in digging pits upon the borders of the sandy downs, sometimes to a depth of more than 130 feet. 4. The last mode is by exploring the precipitous sea cliffs in boats, and detaching masses of loose soil from them with long poles terminating in iron hooks; a very hazardous employment. They search the cliffs with great care at the level, where the amber nodules commonly lie, and loosen the seams with their hooks; in which business the boats are sometimes broken against the precipices, or sunk by an avalanche of rubbish.

Amber occurs in Sicily, disseminated in beds of clay and marl, which lie below the crag limestone. It is accompanied with bitumen; and, though a scanty deposite, it is mined for sale. The pieces are coated with a kind of whitish bark, present a variety of colors, and include many insects. Amber is found in a great many places in the sandy districts of Poland, at a very great distance from the sea, where it is mixed with cones of the pine. In Saxony it is met with in the neighborhood of Pretsch and Wittemberg, in a bituminous clay mingled with lignite. At the embouchure of the Jenissey, in Siberia, it occurs likewise along with lignite; as also in Greenland.

Fine amber is considerably valued for making ornamental objects, and the coarser kinds for certain uses in chemistry, medicine, and the arts. The oriental nations prize more highly than the people of Europe trinkets made of amber; and hence the chief commerce of the Pomeranian article is with Turkey. The Prussian government is said to draw an annual revenue of 17,000 dollars from amber. A good piece of a pound weight fetches 50 dollars. A mass weighing 13 pounds was picked up not long since in Prussia, for which 5000 dollars were offered, and which would bring, in the opinion of the Armenian merchants, from 30,000 to 40,000 dollars at Constantinople. At one time it was customary to bake the opaque pieces of amber in sand, at a gentle heat, for several hours, in order to make it transparent, or to digest it in hot rapeseed oil, with the same view; but how far these processes were advantageous does not appear.

When amber is to be worked into trinkets, it is first split on a leaden plate at a lathe (see Gems, *Cutting of*), and then smoothed into shape on a Swedish whetstone. It is polished on the lathe with chalk and water, or vegetable oil, and finished by friction with flannel. In these processes the amber is apt to become highly electrical, very hot, and even to fly into fragments. Hence, the artists work the pieces time about, so as to keep each of them cool, and feebly excited. The men are often seized with nervous tremors in their wrists and arms from the electricity. Pieces of amber may be neatly joined by smearing their edges with linseed oil, and pressing them strongly together, while they are held over a charcoal fire. Solid specimens of amber, reported to have been altogether fused by a particular application of heat, are now shown in the royal cabinet of Dresden.

A strong and durable *varnish* is made by dissolving amber in drying linseed oil. For this purpose, however, the amber must be previously heated in an iron pot, over a clear red fire, till it soften and be semi-liquefied. The oil, previously heated, is to be now poured in, with much stirring, in the proportion of 10 ounces to the pound of amber; and after the incorporation is complete, and the liquid somewhat cooled, a pound of oil of turpentine must be added. Some persons prescribe 2 ounces of melted shellac, though by this means they are apt to deepen the colour, already rendered too dark by the roasting. The finest varnish is made with oil of spike.

though by this means they are apt to deepen the color, already rendered too dark by the roasting.

The fine black varnish of the coachmakers is said to be prepared by melting 16 ounces of amber in an iron pot, adding to it half a pint of drying linseed oil, boiling hot, of powdered resin and asphaltum 3 ounces each: when the materials are well united, by stirring over the fire, they are to be removed, and, after cooling for some time, a pint of warm oil of turpentine is to be introduced.

The *oil of amber* enters into the composition of the old perfume called *eau de luce;* and is convertible, by the action of a small quantity of strong nitric acid, into a viscid mass like shoemakers' rosin, which has a strong odor of musk, and, under the name of artificial musk, has been prescribed, in acoholic solution, as a remedy against hooping cough, and other spasmodic diseases.

Acid of amber (*succinic acid*) is a delicate reagent, in chemistry, for separating red oxyde of iron from compound metallic solutions.

AMBERGRIS. (*Ambregric*, Fr.; *Ambra*, Germ.)—A morbid secretion of the liver of the spermaceti whale (physeter macrocephalus), found usually swimming upon the sea. It occurs upon the coasts of Coromandel, Japan, the Moluccas, and Madagascar, and has sometimes been extracted from the rectum of whales in the South sea fishery. It has a gray-white color, often with a black streak, or is marbled, yellow and black; has a strong but rather agreeable smell, a fatty taste, is lighter than water, melts at 60° C. (140° F.), dissolves readily in absolute alcohol, in ether, and in both fat and volatile oils. It contains 85 of the fragrant substance called *ambreine.* This is extracted from ambergris by digestion with alcohol of 0·827, filtering the solution, and leaving it to spontaneous evaporation. It is thus obtained in the form of delicate white tufts: which are convertible into ambreic acid by the action of nitric acid. Ambergris is used in perfumery.

AMIANTHUS. A mineral in silky filaments, called also ASBESTUS.

AMMONIA. A chemical compound, called also *volatile alkali.* This substance, in its purest state, is a highly pungent gas, possessed of all the mechanical properties of the air, but very condensable with water. It consists of 3 volumes of hydrogen and 1 of azote condensed into two volumes; and hence its density is 0·591, atmospheric air being 1·000. By strong compression and refrigeration it may be liquefied into a fluid, whose specific gravity is 0·76 compared to water 1·000.

Ammonia gas is composed by weight of 82·53 azote and 17·47 hydrogen in 100 parts. It is obtained by mixing muriate of ammonia, commonly called sal ammoniac, with quicklime, in a retort or still, applying a moderate heat, and receiving the gas either over mercury for chemical experiments, or in water to make liquid ammonia for the purposes of medicine and the arts. Woulfe's apparatus is commonly employed for this condensation.

Ammonia is generated in a great many operations, and especially in the decomposition of many organic substances, by fire or fermentation. Urine left to itself for a few days is found to contain much carbonate of ammonia, and hence this substance was at one time collected in great quantities for the manufacture of certain salts of ammonia, and is still used for its alkaline properties in making alum, scouring wool, &c. When woollen rags, horns, bones, and other animal substances are decomposed in close vessels by fire, they evolve a large quantity of ammonia, which distils over in the form of a carbonate. The main source of ammonia now in this country, for commercial purposes, is the coal gas works. A large quantity of watery fluid is condensed in their tar pits, which contains, chiefly, ammonia combined with sulphureted hydrogen and carbonic acid. When this water is saturated with muriatic acid and evaporated it yields muriate of ammonia, or sal ammoniac, somewhat impure, which is afterwards purified by sublimation. See ARBONATE OF AMMONIA and SAL AMMONIAC.

The soot of chimneys where coal is burned contains both sulphate and carbonate of ammonia, and was extensively employed, at one time, to manufacture these salts.

In making water of ammonia on the great scale, a cast iron still should be preferred, and equal weights of quicklime and sal ammoniac should be brought to the consistence of a pap, with water, before the heat is applied. In this case a refrigeratory worm or globe should be interposed between the adopter tube of the capital of the still and the bottles of Woulfe's apparatus. The muriate of lime, or chloride of calcium, which is left in the still when the whole ammonia is expelled, is of no value. Water is capable of condensing easily about one third of its weight of ammonia gas, or 460 times its bulk. The following table of the quantity of ammonia in 100 parts by weight of its aqueous combinations, at successive densities, is the result of very careful experiments made by me, and recorded in the Philosophical Magazine for March, 1821.

Table of Water of Ammonia or Volatile Alkali, by Dr Ure.

Water of 0·900	Ammonia in 100	Water in 100	Specific gravity by experiment	Mean specific gravity.	Equivalent primes.	
						Wat. Am.
100	26·500	73·500	0·9000			
95	25·175	74·825	0·9045	0·90452		
90	23·850	76·150	0·9090	0·90909	24 + 76	6 to 1
85	22·525	77·475	0·9133	0·91370		
80	21·200	78·800	0·9177	0·91838	21·25 + 78·75,	7 to 1
75	19·875	80·125	0·9227	0·92308		
70	18·550	81·450	0·9275	0·92780	19·1 + 80·9,	8 to 1
65	17·225	82·775	0·9320	0·93264	17·35 + 82·65,	9 to 1
60	15·900	84·100	0·9363	0·93750	15·9 + 84·1,	10 to 1
55	14·575	85·425	0·9410	0·94241	14·66 + 85·34,	11 to 1
50	13·250	86·750	0·9455	0·94737	13·60 + 86·40,	12 to 1
45	11·925	88·075	0·9510	0·95238	11·9 + 88·1,	14 to 1
40	10·600	89·400	0·9564	0·95744	11·2 + 88·8,	15 to 1
35	9·275	90·725	0·9614	0·96256		
30	7·950	92·050	0·9662	0·96774	8·63 + 91·37,	20 to 1
25	6·625	93·375	0·9716	0·97297	7 + 93,	25 to 1
20	5·300	94·700	0·9768	0·97826	6 + 94,	30 to 1
15	3·975	96·025	0·9828	0·98360	4·5 + 95·5,	40 to 1
10	2·650	97·350	0·9887	0·98900	3 + 97,	60 to 1
5	1·325	98·675	0·9945	0·99447		

AMMONIAC, gum-resin. This is the inspissated juice of an umbelliferous plant (the *dorema armeniacum*) which grows in Persia. It comes to us either in small white tears clustered together, or in brownish lumps, containing many impurities. It possesses a peculiar smell, somewhat like that of asafœtida, and a bitterish taste. It is employed in medicine. Its only use in the arts is for forming a cement to join broken pieces of china and glass, which may be prepared as follows: Take isinglass 1 ounce, distilled water 6 ounces, boil together down to 3 ounces, and add 1½ ounce of strong spirit of wine; boil this mixture for a minute or two; strain it; add, while hot, first, half an ounce of a milky emulsion of gum ammoniac, and then five drams of an alcoholic solution of resin mastic. This resembles a substance sold in the London shops, under the name of *diamond cement*. The recipe was given me by a respectable dispensing chemist.

AMORPHOUS. *Without shape.* Said of mineral and other substances which occur in forms not easy to be defined.

AMYGDALINE is a principle of bitter almonds and of bay-laurel berries. It is obtained by digesting, in a retort, alcohol of 0·825 at its boiling temperature upon the meal of bitter almonds, then distilling off the alcohol by the heat of a water-bath till the residuum assumes the consistence of syrup. To the residuum, diluted with a little water, some yeast is to be added, and the mixture is to be set aside in a warm place for some time to ferment. Whenever the fermentation is over, the liquor is to be filtered and evaporated on the water-bath to a syrupy consistence. On mixing this syrup with alcohol of 0·825, the amygdaline falls in a white crystalline powder, which, after being squeezed between folds of filtering-paper, is to be finally purified, by repeated crystallizations, with alcohol. Its crystals are silky-looking scales, or short needles, without smell, but with a slight taste of bitter almonds. When heated, they exhale the fragrance of hawthorn flowers, and burn into a bulky charcoal. Cold alcohol hardly dissolves them, but boiling alcohol pretty copiously. They are very soluble in water, and produce therefrom, by evaporation and cooling, large transparent prisms, of a silky aspect, which contain 6 atoms, or 10·57 per cent. of water. Their composition in the dry state is as follows:

40 atoms of carbon - - - - -	52·98 in 100 parts.
27 — hydrogen - - - - -	5·84 —
1 — azote - - - - -	3·06 —
22 — oxygen - - - - -	38·12 —
1 atom amygdaline (*Liebig*) - - -	100·00

The purpose of the fermentation above prescribed is to decompose a portion of sugar extracted by the alcohol from the bitter almonds along with the amygdaline, of which latter they afford from 3 to 4 per cent.

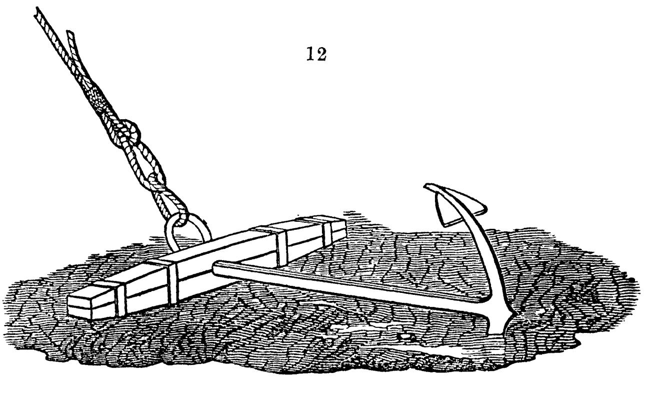
Almonds, both bitter and sweet, contain also another curious principle, called *emulsine* by Liebig, and *synaptase* by Robiquet. It is soluble in water, but is precipitated from it in flakes by alcohol. It coagulates at the temperature of about 140° Fahr. like white of egg. On mixing a solution of 10 parts of amygdaline in 100 parts of water, with 1 part of synaptase in 10 parts of water, a peculiar decomposition immediately takes place. The mixture becomes opaline without losing its transparency; it assumes the odor of bitter almonds, and yields, on distillation, hydrocyanic (prussic) acid, and the hydrure of benzoil (pure essence of bitter almonds), mixed with vapor of water. Coagulated synaptase has no perceptible action on amygdaline. These facts explain a series of puzzling phenomena, which have been long known. Fresh bitter almonds contain emulsine (synaptase), amygdaline, and an unctuous oil, all in such a state that the first two cannot react upon each other; and by removing the water by desiccation their mutual action becomes impossible. On squeezing the almonds the oil is drawn off, and on treating the cake with boiling alcohol the amygdaline is dissolved out, and the synaptase is coagulated; but on moistening the bitter almonds with water the reaction of the two principles becomes instantly effective, as shown by the production of the smell and taste of hydrocyanic acid and of the essential oil. By throwing the bitter almond meal into boiling water the synaptase immediately coagulates, and the above mutual reaction can no longer be obtained, nor the above volatile products. In order properly to prepare the essence of bitter almonds it is therefore necessary to mix 1 part of bitter almond meal with 20 parts of lukewarm water, to leave the mixture to digest for 24 hours, and only then to submit it to distillation. 100 parts of amygdaline produce 47 parts of the crude essence of bitter almonds, which contain 5·9 parts of hydrocyanic acid.

AMYLOXIDE-HYDRATE. See Fusel Oil.

ANALYSIS. The art of resolving a compound substance or machine into its constituent parts. Every manufacturer should so study this art, in the proper treatises, and schools of chemistry or mechanics, as to enable him properly to understand and regulate his business.

ANCHOR. (*Ancre*, Fr.; *Anker*, Germ.) An iron hook of considerable weight and strength, for enabling a ship to lay hold of the ground, and fix itself in a certain situation by means of a rope called the cable. It is an instrument of the greatest importance to the navigator, since upon its taking and keeping hold depends his safety upon many occasions, especially near a lee shore, where he might be otherwise stranded or shipwrecked. Anchors are generally made of wrought iron, except among nations who cannot work this metal well, and who therefore use copper. The mode in which an anchor operates will be understood from inspection of *fig.* 12, where from the direction the strain, it is obvious that the anchor cannot move without ploughing up the ground in which its hook or fluke is sunk. When this, however, unluckily takes place, from the nature of the ground, from the mode of insertion of the anchor, or from the violence of the winds or currents, it is called *dragging the anchor.* When the hold is good, the cable or the buried arm will sooner break than the ship will drive. Anchors are of different sizes, and have different names, according to the purposes they serve; thus there are *sheet*, *best bower*, *small bower*, *spare*, *stream*, and *kedge anchors.* Ships of the first class have seven anchors, and smaller vessels, such as brigs and schooners, three.

12



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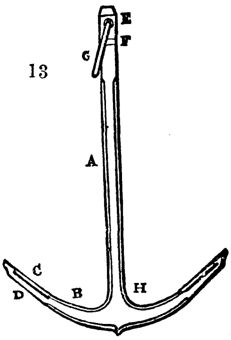


The manufacture of anchors requires great knowledge of the structure of iron, and skill in the art of working it. I shall give, here, a brief notice of the improved system introduced by Mr. Perring, clerk of the cheque at Plymouth, in which the proportions of the parts are admirably adapted to the strains they are likely to suffer. In *fig.* 13 A is the *shank;* B, the *arm* or *fluke;* C, the *palm;* D, the *blade;* E, the *square;* F, the *nut;* G, the *ring;* H, the *crown.*

Formerly the shank was made of a number of square iron rods, laid parallel together in a cylindrical form, and bound by iron hoops. When they were welded into one bar, the exterior rods could not fail to be partially burned and wasted by the strong heat. Mr. Perring abated this evil by using bars of the whole breadth of the shank, and placing them right over each other, hooping them and welding them together at two heats into one solid mass. To any one who has seen the working of puddled iron, with a heavy mill hammer, this operation will not appear difficult.

He formed the crown with bars similarly distributed with those of the shank. His mode of uniting the flukes to the crown is probably the most valuable part of his invention. The bars and half the breadth of the anchor are first welded separately, and then placed side by side, where the upper half is worked into one mass, while the lower part is left disunited, but has carrier iron bars, or *porters*, as these prolongation rods are commonly called, welded to the extremity of each portion. The lower part is now heated and placed in the clamping machine, which is merely an iron plate firmly bolted to a mass of timber, and bearing upon its surface four iron pins. One end of the crown is placed between the first of these pins, and passed under an iron strap; the other end is brought between the other pins, and is bent by the leverage power of the elongated rods or porters.

Thus a part of the arm being formed out of the crown gives much greater security that a true union of fibres is effected, than when the junction was made merely by a short scarf.

The angular opening upon the side opposite B H, *fig.* 13, is filled with the *chock*, formed of short iron bars placed upright. When this has been firmly welded, the truss-piece is brought over it. This piece is made of plates similar to the above, except that their edges are here horizontal. The truss-piece is half the breadth of the arm; so that when united to the crown, it constitutes, with the other parts, the total breadth of the arms at those places.

The shank is now shut upon the crown; the square is formed, and the nuts welded to it; the hole is punched out for the ring, and the shank is then fashioned.

The blade is made much in the way above described. In making the palm, an iron rod is first bent into the approximate form, notching it so that it may more readily take the desired shape. To one end a *porter* rod is fastened, by which the palm is carried and turned round in the fire during the progress of the fabrication. Iron plates are next laid side by side upon the rod, and the joint at the middle is broken by another plate laid over it. When the mass is worked, its under side is filled up by similar plates, and the whole is completely welded; pieces being added to the sides, if necessary, to form the angles of the palm. The blade is then shut on to the palm, after which the part of the arm attached to the blade is united to that which constitutes the crown. The smith-work of the anchor is now finished.

The junction, or shutting on, as the workmen call it, of the several members of an anchor, is effected by an instrument called a *monkey*, which is merely a mass of iron raised to a certain height, between parallel uprights, as in the pile engine or vertical ram, and let fall upon the metal previously brought to a welding heat.

The *monkey* and the *hercules*, both silly, trivial names, are similar instruments, and are usually worked, like a portable pile engine, by the hands of several laborers, pulling separate ropes. Many other modes of manufacturing anchors have been devised, in which mechanical power is more extensively resorted to.

The upper end of the shank F (*fig.* 13) is squared to receive and hold the stock steadily, and keep it from turning. To prevent it shifting along, there are two knobs or tenon-like projections. The point of the angle H, between the arms and the shank, is sometimes called the throat. The arm B C generally makes an angle of 56° with the shank A; it is either round or polygonal, and about half the length of the shank.

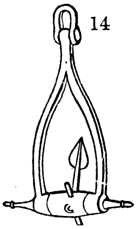
The *stock* of the anchor (*fig.* 12) is made of oak. It consists of two beams which embrace the *square*, and are firmly united by iron bolts and hoops, as shown in the figure. The stock is usually somewhat longer than the shank, has in the middle a thickness about one twelfth of its length, but tapers at its under side to nearly one half this thick ness at the extremities. In small anchors the stock is frequently made of iron; but in this case it does not embrace the anchor, but goes through a hole made in the square, which is swelled out on purpose.

The weight of anchors for different vessels is proportioned to the tonnage; a good rule being to make the anchor in hundred weights one twentieth of the number of tons of the burden. Thus a ship of 1000 tons would require a sheet anchor of 50 cwts. Ships of war are provided with somewhat heavier anchors.

Several new forms and constructions of anchors were proposed under Mr. Piper's patent of November, 1822, by the adoption of which great advantages as to strength were anticipated over every other form or construction previously made.

The particular object was to preserve such a disposition of the fibres of the metal as should afford the greatest possible strength; in doing which the crossing or bending of the fibres at the junctions of the shank, flukes, and crown, where great strength is required, has been avoided as much as possible, so that the fibres are not disturbed or injured.

In this respect most anchors are defective; for in connecting the shanks to the crown-pieces, the grain of the metal is either crossed, or so much curved, as to strain the fibre, and consequently induce a weakness where the greatest strength is required. And, further, the very considerable thicknesses of metal which are to be brought into immediate contact by means of the hammer in forging anchors upon the old construction, render it highly probable that faulty places may be left within the mass, though they be externally imperceptible. Mr. Piper's leading principle was, that the fibre of the metal should run nearly straight in all the parts where strength is particularly required.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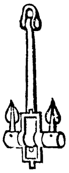
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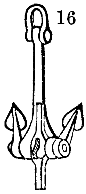
Fig. 14 shows an anchor with one tumbling fluke, which passes through the forked or branched part of the shank. The lower part of this anchor, answering to the crown, has a spindle through it, upon which the fluke turns, and a pin is there introduced for the purpose of confining the fluke when in a holding position. This shank is formed of a solid piece of wrought iron, the fibres of which run straight, and at the crown holes are pierced, which merely bulge the metal without bending the fibres round so as to strain them. The arm and fluke, also, are formed of one piece punched through without curling or crossing the fibre, and the spindle which holds the arm to the crown is likewise straight. This spindle extends some distance on each side of the anchor, and is intended to answer the purpose of a stock; for when either of the ends of the spindle comes in contact with the ground, the anchor will be thrown over into a holding position; or an iron stock may be introduced near the shackle, instead of these projecting ends. In the descent of the anchor, the fluke will fall over towards that side which is nearest the ground, and will there be ready to take hold when the anchor is drawn forward.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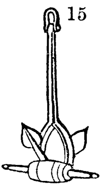
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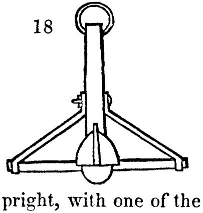
Fig. 15 is another anchor upon the same principle, but slightly varied in form from the last. In this the forked part of the shank is closer than in the former, and there are two arms or flukes connected to the crown-pieces, one of which falls into its holding position as the anchor comes to the ground, and is held at its proper angle by the other fluke stopping against the shank.

Fig. 16 represents another variation in the form of these improved anchors, having two tumbling flukes, which are both intended to take hold of the ground at the same time. The shank is here, as before, made without crossing the grain of the iron, and the eyes for admitting the bolt at the crown and at the shackle are punched out of the solid, not formed by welding or turning the iron round. In this form a guard is introduced at the crown, to answer the purpose of a stock, by turning the flukes over into a holding position. The arms and flukes are made, as before described, of the straight fibre of the iron punched through, and the flukes are fixed to the spindle, which passes through the crown-piece.

Fig. 17 has a shank without any fork, but formed straight throughout; the guard here is an elongated frame of iron, for the same purpose as a stock, and is, with the tumbling flukes, fastened to the spindle, which passes through the crown of the anchor, and causes the flukes to fall into their holding position.

The principles of these new anchors are considered to consist in shanks which are made of straight lengths of metal, and finished so that the fibres of the iron shall not be injured by cross-shuts or uncertain welding; also each arm and palm is made in one solid piece, and finished in straight lines, so that the fibres will not be altered, and the shaft-pin or spindle will also be in one straight line; and this is the improvement claimed. These anchors, being made in separate pieces, give a great advantage to the workman to execute each part perfectly; for he will not have such heavy weights to lift when hot, which will render these anchors much stronger, with less weight; and if any accident should happen to them, any part may be taken separate from the others to be repaired, and several of those parts of the anchor which may be likely to break may be carried on board, in case of accident. This anchor is so contrived that one of thirty hundred weight may be taken to pieces and put together again, by one man, in twenty minutes; it may also be dismounted, and stowed in any part of the ship, in as little room as straight bars of iron, and speedily put together again.

18



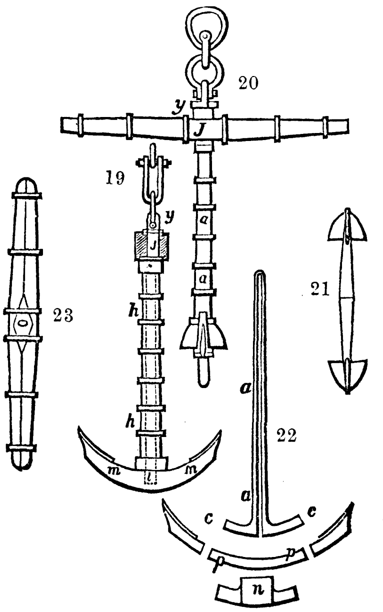
The anchor (*fig.* 18) patented by Mr. Brunton, in February, 1822, has its stock introduced at the crown part, for the purpose of turning it over into a holding position. The shank is perforated through the solid, in two places, with elliptical apertures, for the purpose of giving it a greater stability, and more effectually resisting the strain to which the anchor may be subjected. The stock is a cylindrical iron rod, held at its extremities by lateral braces, which are bolted to the shank.

Fig. 18 shows the form of the anchor. The shank is seen upright, with one of the flukes projecting in its front; the horizontal iron stock is at bottom; and the oblique braces are bolted to both shank and stock. The ends of the stock, from the shoulder, are formed dove-tailed, and oval in the vertical direction, and are protruded through apertures in the braces, also oval, but in the horizontal direction, and counter sunk. When the ends of the stock have been thus introduced through the holes, the braces are securely bolted to the shank, the ends of the stock are then spread, by hammering into the counter-sunk holes of the braces, and by that means they are made firm.

An anchor of this description is considered by the patentee to possess considerable advantage, particularly in point of stability, over the ordinary construction of anchors, and is economical, inasmuch as a less weight of metal will give, upon this plan, an equal degree of strength.

An ingenious form of anchor was made the subject of a patent, by Lieutenant Rodgers, of the Royal Navy, in 1828, and was afterwards modified by him in a second patent, obtained in August, 1829. The whole of the parts of the anchor are to be bound together by means of iron bands or hoops, in place of bolts or pins.

Fig. 19 is a side view of a complete anchor, formed upon his last improved construction, and *fig.* 20, a plan of the same; *fig.* 21, an end view of the crown and flukes, or arms; *fig.* 22 represents the two principal iron plates, *a*, *a*, of which the shank is constructed, but so as to form parts of the stump arms to which the flukes are to be connected.



The crown piece is to be welded to the stump piece, *c*, *c*, *fig.* 22, as well as to the end *l* of the centre piece *h h*, and the scarfs *m m* are to be cut to receive the arms or flukes. Previously, however, to uniting the arms or flukes with the stump arms, the crown and throat of the anchor are to be strengthened, by the application of the crown slabs *n n*, *fig.* 22, which are to be welded upon each side of the crown, overlapping the end of the pillar *h*, and the throat or knees of the stump arms and the crown piece. The stump arms are then to be strengthened in a similar manner, by the thin flat pieces *p p*, which are to be welded upon each side. The palms are united to the flukes in the usual way, and the flukes are also united to the stump arms by means of the long scarfs *m m*. When the shank of the anchor has been thus formed, and united with the flukes, the anchor smith's work may be said to be complete.

Another of the improvements in the construction of anchors, claimed under this patent, consists in a new method of affixing the stock upon the shank of the anchor, which is effected in the following manner: in *fig.* 20, the stock is shown affixed to the anchor; in *fig.* 23 it is shown detached. It may be made either of one or two pieces of timber, as may be found most convenient. It is, however, to be observed, that the stock is to be completed before fitting on to the shank. After the stock is shaped, a hole is to be made through the middle of it, to fit that part of the shank to which it is to be affixed. Two stock plates are then to be let in, one on each side of the stock, and made fast by counter sunk nails and straps, or hoops; other straps or hoops of iron are also to be placed round the stock, as usual.

In place of nuts, formed upon the shank of the anchor, it is proposed to secure the stock by means of a hoop and a key, shown above and below J, in *fig.* 20. By this contrivance, the stock is prevented from going nearer to the crown of the anchor than it ought to do, and the key prevents it from sliding towards the shackle.

Since fitting the stock to the shank of an anchor, by this method, prevents the use of a ring, as in the ordinary manner, the patentee says that he in all cases substitutes a shackle for the ring, and which is all that is required for a chain cable; but, when a hempen cable is to be used, he connects a ring to the usual shackle, by means of a joining shackle, as in *figs.* 19 and 20.

Mr. Rodgers proposes under another patent, dated July, 1833, to alter the size and form of the palms; having found from experience that anchors with small palms will not only hold better than with large ones, but that the arms of the anchor, even without any palms, have been found to take more secure hold of the ground than anchors of the old construction, of similar weight and length. He has, accordingly, fixed upon one-fifth of the length of the arm, as a suitable proportion for the length or depth of the palm. He makes the palms, also, broader than they are long or deep.

ANILINE. An organic compound, which may be procured in several ways: 1, when isatine (see Indigo) is fused with solid hydrate of potash; 2, when to an alcoholic solution of benzine a little zinc and muriatic acid is added: but it is obtained best from coal tar, which is to be distilled in a large iron retort, and the successive products to be separately received, especially the latter and denser ones. This heavy tar-oil is to be strongly agitated along with muriatic acid in a glass globe. The acid solution contains the aniline, which, being of an alkaline nature, is called a volatile base. It must be subjected to an operose process of purification, with milk of lime, &c., too complex to be detailed here, as no useful application of it in the arts has hitherto been made. Dr. Hofmann has written many elaborate papers upon aniline, and its saline combinations.

ANIMÉ. A resin of a pale brown yellow color, transparent and brittle. It exudes from the courbaril of Cayenne, a tree which grows also in various parts of South America. It occurs in pieces of various sizes, and it often contains so many insects belonging to living species, as to have merited its name, as being animated. It contains about a fifth of one per cent. of a volatile oil, which gives it an agreeable odor. Alcohol does not dissolve the genuine animé, as I have ascertained by careful experiments; nor does caoutchoucine, but a mixture of the two, in equal parts, softens it into a tremulous jelly, though it will not produce a liquid solution. When reduced to this state, the insects can be easily picked out, without injury to their most delicate parts.

The specific gravity of the different specimens of animé which I tried varied from 1·054 to 1·057. When exposed to heat, in a glass retort over a spirit flame, it softens, and, by careful management, it may be brought into liquid fusion, without discolouration. It then exhales a few white vapors, of an ambrosiacal odor, which being condensed in water, and the liquid being tested, is found to be succinic acid. *Author.*

It is extensively used by the varnish-makers, who fuse it at a pretty high heat, and in this state combine it with their oils or other varnishes.

ANKER. A liquid measure of Amsterdam, which contains 32 gallons English.

ANNEALING or NEALING. (*Le recuit,* Fr.; *das anlassen,* Germ.) A process by which glass is rendered less frangible; and metals, which have become brittle, either in consequence of fusion or long-continued hammering, are again rendered malleable. When a glass vessel is allowed to cool immediately after being made, it will often sustain the shock of a pistol-bullet, or any other blunt body falling into it from a considerable height; while a small splinter of flint, or an angular fragment of quartz, dropped gently into it, makes it sometimes immediately, sometimes after a few minutes, fly to pieces with great violence. This extreme fragility is prevented by annealing, or placing the vessels in an oven where they take several hours or even some days to cool. Similar phenomena are exhibited in a higher degree by glass-tears, or Prince Rupert's drops. They are procured by letting drops of melted glass fall into cold water. Their form resembles that of a pear, rounded at one extremity, and tapering to a very slender tail at the other. If a part of the tail be broken off, the whole drop flies to pieces with a loud explosion; and yet the tail of a drop may be cut away by a glass-cutter's wheel. or the thick end may be struck smartly with a hammer, without the fear of sustaining any injury. When heated to redness, and permitted to cool gradually in the open air, they lose these peculiarities, and do not differ sensibly from common glass.

The properties of unannealed glass depend on a peculiar structure, extending uniformly through its whole substance; and the bursting of a glass drop by breaking off the tail, or of an unannealed glass vessel, by dropping a piece of flint into it, arises from a crack being thus begun, which afterwards extends its ramifications in different directions throughout the glass.

When metals have been extended to a certain degree under the hammer, they become brittle, and incapable of being further extended without cracking. In this case the workman restores their malleability by annealing, or heating them red-hot. The rationale of this process seems to be, that the hammering and extension of the metal destroy the kind of arrangement which the particles of the metal had previous to the hammering; and that the annealing, by softening the metal, enables it to recover its original structure.

Of late years a mode has been discovered of rendering cast iron malleable, without subjecting it to the action of puddling. The process is somewhat similar to that employed in annealing glass. The metal is kept for several hours at a temperature a little below its fusing point, and then allowed to cool slowly. In this manner vessels are made of cast iron which can sustain considerable violence, without being broken. See Steel, softening of.

ANNOTTO. (*Rocou*, or *roucou*, Fr.; *orleans*, Germ.) A somewhat dry and hard paste, brown without, and red within. It is usually imported in cakes of two or three pounds weight, wrapped up in leaves of large reeds, packed in casks, from America, where it is prepared from the seeds of a certain tree, the *bixa orellana*, of Linnæus.

The pods of the tree being gathered, their seeds are taken out and bruised; they are then transferred to a vat, which is called the steeper, where they are mixed with as much water as covers them. Here the substance is left for several weeks, or even months; it is now squeezed through sieves placed above the steeper, that the water containing the coloring matter in suspension may return into the vat. The residuum is preserved under the leaves of the anana (pine-apple) tree, till it becomes hot by fermentation. It is again subjected to the same operation, and this treatment is continued till no more color remains.

The substance thus extracted is passed through sieves, in order to separate the remainder of the seeds, and the color is allowed to subside. The precipitate is boiled in coppers till it be reduced to a consistent paste; it is then suffered to cool, and dried in the shade.

Instead of this long and painful labor, which occasions diseases by the putrefaction induced, and which affords a spoiled product, Leblond proposes simply to wash the seeds of annotto till they be entirely deprived of their color, which lies wholly on their surface; to precipitate the color by means of vinegar or lemon juice, and to boil it up in the ordinary manner, or to drain it in bags, as is practised with indigo.

The experiments which Vauquelin made on the seeds of annotto imported by Leblond, confirmed the efficacy of the process which he proposed; and the dyers ascertained that the annotto obtained in this manner was worth at least four times more than that of commerce; that, moreover, it was more easily employed; that it required less solvent; that it gave less trouble in the copper, and furnished a purer color.

Annotto dissolves better and more readily in alcohol than in water, when it is introduced into the yellow varnishes for communicating an orange tint.

The decoction of annotto in water has a strong peculiar odor, and a disagreeable taste. Its color is yellowish-red, and it remains a little turbid. An alkaline solution renders its orange-yellow clearer and more agreeable, while a small quantity of a whitish substance is separated from it, which remains suspended in the liquid. If annotto be boiled in water along with an alkali, it dissolves much better than when alone, and the liquid has an orange hue.

The acids form with this liquor an orange-colored precipitate, soluble in alkalies, which communicate to it a deep orange color. The supernatant liquor retains only a pale yellow hue.

When annotto is used as a dye, it is always mixed with alkali, which facilitates its solution, and gives it a color inclining less to red. The annotto is cut in pieces, and boiled for some instants in a copper with its own weight of crude pearl ashes, provided the shade wanted do not require less alkali. The cloths may be thereafter dyed in this bath, either by these ingredients alone, or by adding others to modify the color; but annotto is seldom used for woollen, because the colors which it gives are too fugitive, and may be obtained by more permanent dyes. Hellot employed it to dye a stuff, prepared with alum and tartar; but the color acquired had little permanence. It is almost solely used for silks.

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For silks intended to become aurora and orange, it is sufficient to scour them at the rate of 20 per cent. of soap. When they have been well cleansed, they are immersed in a bath prepared with water, to which is added a quantity of alkaline solution of annotto, more or less considerable according to the shade that may be wanted. This bath should have a mean temperature, between that of tepid and boiling water.

When the silk has become uniform, one of the hanks is taken out, washed, and wrung, to see if the color be sufficiently full; if it be not so, more solution of annotto is added, and the silk is turned again round the sticks: the solution keeps without alteration.

When the desired shade is obtained, nothing remains but to wash the silk, and give it two beetlings at the river, in order to free it from the redundant annotto, which would injure the lustre of the color.

When raw silks are to be dyed, those naturally white are chosen, and dyed in the annotto bath, which should not be more than tepid, or even cold, in order that the alkali may not attack the gum of the silk, and deprive it of the elasticity which it is desirable for it to preserve.

What has been now said regards the silks to which the aurora shades are to to be given; but to make an orange hue, which contains more red than the aurora, it is requisite, after dyeing with annotto, to redden the silks with vinegar, alum, or lemon juice. The acid, by saturating the alkali employed for dissolving the annotto, destroys the shade of yellow that the alkali had given, and restores it to its natural color, which inclines a good deal to red.

For the deep shades, the practice at Paris, as Macquer informs us, is to pass the silks through alum; and if the color be not red enough, they are passed through a faint bath of brazil wood. At Lyons, the dyers who use carthamus, sometimes employ old baths of this ingredient for dipping the deep oranges.

When the orange hues have been reddened by alum, they must be washed at the river; but it is not necessary to beetle them, unless the color turns out too red.

Shades may be obtained also by a single operation, which retain a reddish tint, employing for the annotto bath a less proportion of alkali than has been pointed out.

Guhliche recommends to avoid heat in the preparation of annotto. He directs it to be placed in a glass vessel, or in a glazed earthen one; to cover it with a solution of pure alkali; to leave the mixture at rest for 24 hours; to decant the liquor, filter it, and add water repeatedly to the residuum, leaving the mixture each time at rest for two or three days, till the water is no longer colored; to mix all these liquors, and preserve the whole for use in a well-stopped vessel.

He macerates the silk for 12 hours in a solution of alum, at the rate of an eighth of this salt for one part of silk, or in a water rendered acidulous by the aceto-citric acid above described; and he wrings it well on its coming out of this bath.

Silk thus prepared is put into the annotto bath quite cold. It is kept in agitation there till it has taken the shade sought for; or the liquor may be maintained at a heat far below ebullition. On being taken out of the bath, the silk is to be washed and dried in the shade.

For lighter hues, a liquor less charged with color is taken; and a little of the acid liquid which has served for the mordant may be added, or the dyed silk may be passed through the acidulous water.

We have seen the following preparation employed for cotton velvet:—one part of quicklime, one of potash, two of soda.

Of these a ley is formed, in which one part of annotto is dissolved; and the mixture is boiled for an hour and a half. This bath affords the liveliest and most brilliant auroras. The buff (chamois) fugitive dye is also obtained with this solution. For this purpose only a little is wanted; but we must never forget, that the colors arising from annotto are all fugitive.

Dr. John found in the pulp surrounding the unfermented fresh seeds, which are about the size of little peas, 28 parts of coloring resinous matter, 26·5 of vegetable gluten, 20 of ligneous fibre, 20 of coloring extractive matter, 4 formed of matters analogous to vegetable gluten and extractive, and a trace of spicy and acid matters.

The Gloucestershire cheese is colored with annotto, in the proportion of one cwt. to an ounce of the dye.

When used in calico-printing, it is usually mixed with potash or ammonia and starch.

It is an appropriate substance for tinging varnishes, oils, spirits, &c.

The following statement gives an account of the quantities imported and exported with the nett revenue, during the following years:—

		1841.	1842.	1843.	1844.
Quantities imported	cwt.	——	2319	3271	3494
Quantities exported	cwt.	——	513	229	307
Retained for consumption	cwt.	——	3197	3347	2689
Nett Revenue	£.	154	185	175	144

ANTHRACITE, from ανθραξ, coal, is a species of coal found in the transition rock formation, and is often called stone coal. It has a grayish black, or iron black color, an imperfectly metallic lustre, conchoidal fracture, and a specific gravity of from 1·4 to 1·6, being, therefore, much denser than the coal of the proper coal measures. It consists wholly of carbon, with a small and variable proportion of iron, silica, and alumina. It is difficult to kindle in separate masses, and burns when in heaps or grates without smell or smoke, leaving sometimes an earthy residuum. It has been little explored or worked in the old world; but is extensively used in the United States of America, and has become of late years a most valuable mineral to that country, where it is burned in peculiar grates, adapted to its difficult combustion. In Pensylvania, the anthracite coal formation has been traced through a tract many miles in width, and extending across the two entire counties of Luzerne and Schuylkill. At Mauch Chunk, upon the Lehigh, 800 men were employed so far back as 1825, in digging this coal. In that year 750,000 bushels were dispatched for Philadelphia. It is worked there with little cost or labor, being situated on hills from 300 to 600 feet above the level of the neighboring rivers and canals, and existing in nearly horizontal beds, of from 15 to 40 feet in thickness, covered by only a few feet of gravelly loam. At Portsmouth, in Rhode Island, an extensive stratum of this coal has been worked, with some interruptions, for 20 years; and more recently a mine of anthracite has been opened at Worcester, in Massachusetts, at the head of the Blackstone canal. It has been of late employed in South Wales for smelting iron, and in a cupola blast furnace.

ANTIGUGGLER. A small syphon of metal, which is inserted into the mouths of casks, or large bottles, called carboys, to admit air over the liquor contained in them, and thus to facilitate their being emptied without agitation or a guggling noise.

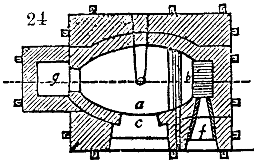
ANTIMONY. (*Antimoine*, Fr.; *Spiessglanz*, or *Spiessglass*, Ger.) The only ore of this metal found in sufficient abundance to be smelted is the sulphuret, formerly called crude antimony. It occurs generally in masses, consisting of needles closely aggregated, of a metallic lustre; a lead-gray color, inclining to steel-gray, which is unchanged in the streak. The needles are extremely brittle, and melt even in the flame of a candle, with the exhalation of a sulphureous smell. The powder of this sulphuret is very black, and was employed by women in ancient times to stain their eyebrows and eyelids. This ore consists in 100 parts of 72·86 metal, and 27·14 sulphur. Specific gravity from 4.13 to 4·6.

The veins of sulphuret of antimony occur associated with gangues of quartz, sulphate of barytes, and carbonate of lime; those of Allemont occur in the numerous fissures of a mica schist, evidently primitive. Of late years very productive mines of antimony have been found in Borneo, which have furnished great importations to this country.

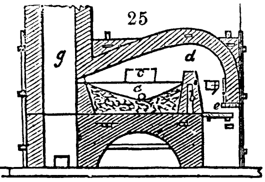
In treating the ore to obtain the metal, the first object is to separate the gangue, which was formerly done by filling crucibles with the mixed materials, placing them on the hearth of an oven, and exposing them to a moderate heat. As the sulphuret easily melts, it ran out through a hole in the bottom of the crucible into a pot placed beneath, and out of the reach of the fire. But the great loss from breakage of the crucibles has caused another method to be adopted. In this the broken ore, being sorted, is laid on the bottom of a concave reverberatory hearth, wherere it is reduced.

Figs. 24, 25, represent a wind or flame furnace, for the reduction of antimony. The hearth is formed of sand and clay solidly beat together, and slopes from all sides towards the middle, where it is connected with the orifice *a*, which is closed with dense coal-ashes; *b* is the air channel up through the bridge; *c*, the door for introducing the prepared ore, and running off the slags; *d*, the bridge; *e*, the grate; *f*, the fire or fuel-door; *g*, the chimney. With 2 or 3 cwt. of ore, the smelting process is completed in from 8 to 10 hours. The metal thus obtained is not pure enough, but must be fused under coal dust, in portions of 20 or 30 pounds, in crucibles placed upon a reverberatory hearth.

24



25



To obtain antimony free from iron, it should be fused with some antimonic oxide in a crucible, whereby the iron is oxidized and separated. The presence of arsenic in antimony is detected by the garlic smell, emitted by such an alloy when heated at the blow-pipe; or, better, by igniting it with nitre in a crucible; in which case insoluble antimonite and antimoniate of potash will be formed along with soluble arseniate. Water digested upon the mixture, filtered, and then tested with nitrate of silver, will afford the brown-red precipitate characteristic of arsenic acid.

According to Berthier, the following materials afford, in smelting, an excellent product of antimony: 100 parts of sulphuret; 60 of hammerschlag (protoxide of iron from the shingling or rolling mills); 45 to 50 of carbonate of soda; and 10 of charcoal powder. From 65 to 70 parts of metallic antimony or regulus should be obtained. Glauber salts may be used advantageously instead of soda. Another formula is 100 parts of sulphuret of antimony; 42 of metallic iron, and 10 of dry sulphate of soda. The product thence is said to be from 60 to 64 parts of metal.

In the works where antimonial ores are smelted, by means of tartar (argol), the alkaline scoriæ, which cover the metallic ingots, are not rejected as useless, for they hold a certain quantity of antimonial oxide in combination; a property of the potash flux, which is propitious to the purity of the metal. These scoriæ, consisting of sulphuret of potassium and antimonite of potash, being treated with water, undergo a reciprocal decomposition; the elements of the water act on those of the sulphuret, and the resulting alkaline hydro-sulphuret re-acts on the antimonial solution, so as to form a species of *kermes mineral*, which precipitates. This is dried, and sold at a low price as a veterinary medicine, under the name of *kermes*, by the dry way.

Metallic antimony, as obtained by the preceding process, is the antimony of commerce, but is not absolutely pure; containing frequently minute portions of iron, lead, and even arsenic; the detection and separation of which belong to the sciences of chemistry and pharmacy; but considerable purity may be secured by fusing the metal, mixed with a little of its sulphuret and some carbonate of soda, repeatedly in a crucible From 100 parts of the impure metal in this way 94 of pure antimony are obtained. The addition of sulphuret serves the purpose, making fluid compounds of the sulphurets of iron, arsenic, and copper, with the soda. Wöhler purifies antimony completely from arsenic (not from iron and copper), by deflagrating 10 parts of the crude ore with 12 of nitre and 15 of carbonate of soda; washes away the arsenic salt, and then smelts the residuary antimoniate of potash with black flux. Lead can be separated only by the humid analysis.

Antimony is a brittle metal, of a silvery white color, with a tinge of blue, a lamellar texture, and crystalline fracture. When heated at the blow-pipe, it melts with great readiness, and diffuses white vapors, possessing somewhat of a garlic smell. If thrown in this melted state on a sheet of flat paper, the globule sparkles and bursts into a multitude of small spheroids, which retain their incandescence for a long time, and run about on the paper, leaving traces of the white oxide produced during the combustion. When this oxide is fused with borax, or other vitrefying matter, it imparts a yellow color to it. Metallic antimony, treated with hot nitric acid in a concentrated state, is converted into a powder, called antimonious acid, which is altogether insoluble in the ordinary acid menstrua; a property by which the chemist can separate that metal from lead, iron, copper, bismuth, and silver. According to Bergmann, the specific gravity of antimony is 6·86; but that of the purest is 6·715. The alchemists had conceived the most brilliant hopes of this metal; the facility with which it is alloyed with gold, since its fumes alone render this most ductile metal immediately brittle, led them to assign to it a royal lineage, and distinguish it by the title of *regulus*, or the little king.

Its chief employment now is in medicine, and in making the alloys called type metal, stereotype metal, music plates, and Britannia metal; the first consisting of 6 of lead and 2 of antimony; the second of 6 of lead and 1 of antimony; the third of lead, tin, and antimony; and the fourth also of lead, tin, and antimony, with occasionally a little copper and bismuth.—For Glass of Antimony, see Pastes.

ANTISEPTICS. Substances which counteract the spontaneous decomposition of animal and vegetable substances. These are chiefly culinary salt, nitre, spices, and sugar, which operate partly by inducing a change in the animal or vegetable fibres, and partly by combining with and rendering the aqueous constituent unsusceptible of decomposition. See Provisions, curing of, and Preserved Meats.

ANVIL. A mass of iron, having a smooth, and nearly flat top surface of steel; upon which blacksmiths, and various other artificers, forge metals with the hammer. The common anvil is usually made of seven pieces: 1, the core, or body; 2, 3, 4, 5, the four corner pieces which serve to enlarge its base; 6, the projecting end, which has a square hole for the reception of the tail or shank of a chisel on which iron bars may be cut through; and 7, the beak, or horizontal cone round which rods or slips of metal may be turned into a circular form, as in making rings. These 6 pieces are welded separately to the first, or core, and then hammered into a uniform body. In manufacturing large anvils two hearths are needed, in order to bring each of the two pieces to be welded to a proper heat by itself; and several men are employed in working them together briskly in the welding state, by heavy swing hammers. The steel facing is applied by welding in the same manner. The anvil is then hardened by heating it to a cherry red, and plunging it into cold water; a running stream being preferable to a pool or cistern. The facing should not be too thick a plate, for, when such, it is apt to crack in the hardening. The face of the anvil is now smoothed upon a grindstone, and finally polished with emery and crocus, for all delicate purposes of art.

The blacksmith, in general, sets his anvil loosely upon a wooden block, and in preference on the root of an oak. But the cutlers and file-makers fasten their anvils to a large block of stone; which is an advantage, for the more firmly and solidly this

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tool is connected to the earth, the more efficacious will be the blows of the hammer on any object placed upon it.

AQUAFORTIS. Nitric acid, somewhat dilute, was so named by the alchemists on account of its strong solvent and corrosive operation upon many mineral, vegetable, and animal substances. See Nitric Acid.

AQUA REGIA. The name given by the alchemists to that mixture of nitric and muriatic acids which was best fitted to dissolve gold, styled by them the king of the metals. It is now called *nitro-muriatic acid.*

AQUA VITÆ. The name very absurdly given to alcohol, when used as an intoxicating beverage. It has been the *aqua mortis* to myriads of the human race; and will, probably, ere long, destroy all the native tribes of North America and Australia.

ARABLE LAND may be regarded with Thaer as consisting of one or other of the following sorts of soils:—

No.		Clay per Cent.	Sand per Cent.	Carb. of Lime per Cent.	Humus per Cent.	Value.
1	First class of strong wheat soils - - - - -	74	10	4½	11·5	100
2		81	6	4	8·4	98
3		79	10	4	6·5	96
4		40	22	36	4	90
5	Rich light sand in natural grass - - - - - -	14	49	10	27	3
6	Rich barley land - - -	20	67	3	10	78
7	Good wheat land - - -	58	36	2	4	77
8	Wheat land - - - -	56	30	12	2	75
9	Do. - - - -	60	38	Very insignificant quantities.	2	70
10	Do. - - - -	48	50		2	65
11	Do. - - - -	68	30		2	60
12	Good barley land - - -	38	60		2	60
13	Do. Second quality -	33	65		2	50
14	Do. - - - -	28	70		2	40
15	Oat land - - - -	23½	75		1·5	30
16	Do. - - - - -	18½	80		1·5	20

Below this are very poor lands.

In all these soils the depth is supposed the same, and the quality uniform to the depth of at least 6 inches; the subsoil sound, and neither too wet nor too dry.

Nos. 1, 2, & 3, are alluvial soils; and from the division and intimate union of the humus, are not so heavy and stiff as the quantity of clay would indicate.

No. 4, is a rich clay loam, such as is found in many parts of England, neither too heavy nor too loose; a soil easily kept in heart by judicious cultivation.

No. 5, is very light and rich, and best adapted for gardens and orchards, but not for corn; hence its comparative value can scarcely be given.

Nos. 6, 7, & 8, are good soils. The quantity of carbonate of lime in No. 8 compensates for the smaller portion of humus. This land requires manure, as well as the others below. In those from No. 9, downwards, lime or marl would be the greatest improvement. Nos. 15 and 16 are poor light soils, requiring clay and much manure; but even these lands will pay the cost of judicious cultivation, and rise in value.

The last column, of comparative value, is the result of several years' careful valuation of the returns, after labor and seed had been deducted.

Few soils in England contain more than 4 or 5 per cent. of humus, even when in a very good heart; and 2 per cent., with a good loamy texture, will render a soil fit for corn with judicious cultivation. The texture is of most importance, as may be seen by comparing Nos. 7 & 8 with No. 6. If this is of good quality, dung will soon give the proper supply of humus.

The depth of the soil and the nature of the subsoil greatly affect its value. However rich it may be, if there is only a thin layer of good soil over a sharp gravel or a wet clay, it can never be very productive: in the first, it will be parched in dry weather; and in the latter, converted into mud by every continued rain. If the subsoil be loam or chalk, 6 inches of good soil will be sufficient. With a foot of good soil, the subsoil is of little consequence, provided it be dry, and the water can find a ready outlet. The best alluvial soils are generally deep, the chalky shallow.

The exposure with respect to the sun, and the declivity of the ground, are very important circumstances, and equivalent to an actual difference in the climate. A gentle declivity towards the south, and a shelter against cold winds, may make as great a difference as several degrees of latitude; and in comparing the value of similar lands in different climates, the average heat and moisture in each must be accurately known. A soil very fertile in the south of Europe may be very unproductive in England; and a light soil of some value in the west of Scotland might be absolutely barren in Italy or Spain.

2. *Cultivation of the Soil.*—The better the soil, the less cultivation it requires to produce tolerable crops; hence, where the land is very rich, we find in general a slovenly culture; where the ground is less productive, more labor and skill are applied to compensate for the want of natural fertility. The simplest cultivation is that of the spade, the hoe, and the rake; and, on a small scale, it is the best: but spade husbandry cannot be carried to a great extent without employing more hands than can be spared from other occupations. The plough, drawn by oxen or horses, is the chief instrument of tillage, and has been so in all ages and nations of which we have any records. Its general form is familiar to every one, and requires no minute description. A plough should as much as possible imitate the work done with a spade. It should cut a slice from the land by its coulter vertically, and by the share horizontally lift it up, and turn it quite over by means of the mould board; and the art of the ploughman consists in doing this perfectly, and with such a depth and width as suit the soil and the intended purpose. In rich mellow soils a ploughed field should differ little from a garden dug with a spade. In tenacious soils, the slice will be continued without breaking, especially if bound by the fibres and roots of plants; the whole surface will be turned over, and the roots exposed to the air. It is of great consequence that each slice be of the same width, and thickness, and the sides of it perfectly straight and parallel. The plane of the coulter must be perfectly vertical, and that of the share horizontal, in order that the bottom of the furrow may be level, without hollows or *baulks*, which are irregularities produced by the rising or sinking of the plough, or inclining it to either side. The ancients were very particular in this respect, and recommended sounding the earth with a sharp stake, to ascertain whether the ploughman had done his duty. There are various modes of ploughing land, either quite flat, or in lands or stitches, as they are called in England, and in Scotland riggs; that is, in portions of greater or less width, with a double furrow between them, somewhat like beds in a garden. Sometimes two ridges are set up against each other, which is called ridging or *bouting*. The land, then, is entirely laid in ridges and deep furrows, by which it is more exposed to the influence of the atmosphere and kept drier. This is generally done before winter, especially in stiff wet soils. Sometimes two or more ridges are made on each side, forming narrow stitches. When the ground is to be ploughed without being laid in lands or stitches, and all the ridges inclined one way, the mould board of the plough is shifted at each turn from one side to the other. The plough which admits of this is called a *turn-wrest plough*, and is in general use in Kent and in many parts of the Continent, where the subsoil is dry and the land not too moist. In most other situations the ground is laid in *lands*, and the mould board of the plough is fixed on the right side. When grass land or stubble is ploughed, care must be taken to bury the grass and weeds completely; and the slice cut off by the plough must be turned over entirely, which is best done by making the width of the furrow greater than the depth. When the grass and weeds are rotten, and the ground is ploughed to pulverize it, a narrow deep furrow is best. The earth ploughed up is laid against the side of the preceding ridge, which forms a small furrow between the tops of the ridges, well adapted for the seed to lodge in, and to be readily covered with the harrows.

Nothing has divided both practical and theoretical agriculturists more than the question whether the land should be ploughed deep or shallow; but a very slight attention to the purposes for which land is ploughed, and to the nature of the soil, will readily reconcile these apparently contradictory opinions. A deep, rich, and stiff soil can never be moved too much nor too deep. Deep ploughing brings up rich earth, admits the air and water readily, and gives room for the roots to shoot, while the rich compact soil affords moisture and nourishment. Wherever trees are to be planted, the ground should be stirred as deep as possible, even in a poor soil. For grass and corn this is not always prudent; their roots seldom go above 3 or 4 inches deep; and if they find sufficient moisture and humus, they require little more depth.

Whenever the soil below a certain depth is of an inferior quality, there can be no use in bringing it up; and where the soil is light and porous, the bottom had much better not be broken. Norfolk farmers know this well, and are very careful not to break the *pan*, as they call it, in their light lands. This pan is formed by the pressure of the sole of the plough and the tread of the horses, and opposes a useful bank to the too rapid filtration of the water. It lies from 5 to 8 inches below the surface. If it is broken, the manure is washed down into the light subsoil, and the crop suffers, especially when sheep have been folded, their dung being very soluble. In such soils an artificial pan may be formed by the *land-presser* or press-drill. This instrument consists of two very heavy cast-iron wheels, with angular edges, set on an axle, at a distance from each other equal to the width of the furrows, and a lighter wheel to keep the instrument vertical.

It is drawn by a horse immediately after the plough, pressing two furrows at once, and going twice over each furrow. It leaves the land in regular drills; and the seed sown by hand falls into the bottom of the drills, and is covered by the harrows. When the plants come up, they appear in regular parallel rows.

The great object in ploughing land is to divide it, expose every part of it to the influence of the elements, and destroy every plant or weed but those which are sown in it. To do this perfectly requires several ploughings, with certain intervals; and during that time no crop can be upon the land. This is the real use of fallows, and not, as was once supposed, to allow the land to rest; on the contrary, it ought then to have the least repose.

Where the soil is good, with a porous subsoil, the greatest care should be taken not to go too deep; but where the subsoil is compact and impervious to water, but not wet for want of outlet or draining, it is useful to stir the soil to a great depth, but without bringing it to the surface, which may be done by a plough without a mould board following a common plough in the same furrow. This is an excellent mode of draining; and at the same time keeping a reservoir of moisture, which in dry weather ascends in vapors through the soil and refreshes the roots.

The mode in which the soil is prepared most perfectly for the reception of the seed is best shown by following the usual operations on fallows. After the harvest, the plough is set to work, and the stubble ploughed in. The winter's frost and snow mellow it, while the stubble and weeds rot below. In spring, as soon as the weather permits, it is ploughed again, the first ridges being turned over as they were before. This completes the decomposition of the roots and weeds. It is then stirred with harrows or other instruments, which tear up the roots which remained; and some of these not being easily destroyed, are carefully gathered and burnt, or put in a heap to ferment and rot, a portion of quicklime being added. Another ploughing and stirring follows, at some interval, till the whole ground is mellow, pulverized, and free from weeds; manure is put on if required, and immediately spread and ploughed in; the land is then prepared for the seed.

There is no method yet found out of ascertaining the comparative state of land which has been exhausted. It would be a discovery well worth the attention of modern chemists, who have made such progress lately in the analysis of vegetable substances, and would be invaluable to farmers and proprietors of land. In the meantime the nature of the weeds which abound on the land will give some clue to its state; and an experienced person will collect from various minute appearances in the soil whether it has been fairly managed or exhausted. It is in general more advantageous to take a farm in a district with which you are well acquainted. It will be a great advantage if you have had an opportunity of seeing the land at all times, observing it in different seasons and states of the weather, and especially of seeing the crops thrashed out, and ascertaining the quantity of corn which is usually yielded from a certain quantity of straw, for lands very similar in outward appearance will produce a very different return when the crops are thrashed. A want of attention to these circumstances is the cause that a man who comes from a distant part of the country, and hires a farm on his own judgment, seldom succeeds so well as might be expected, even with a superior knowledge of agriculture. He naturally compares the soil with some similar soil which he has been acquainted with. If he comes from a district where the soil is sandy, and where clay is in request, he will give the preference to very stiff loams; if he comes from a cold wet clay, he will prefer the sandy; and the chances are, that he is mistaken in his judgment, and finds it out when he has already embarked his capital in a losing concern. Next to the nature of the soil is to be considered the convenient situation of the farm, the disposition of the fields, and the adaptation of the farm-buildings to the most profitable occupation of the land. The roads, especially those which lead to the neighboring towns, whence manure may be obtained, are a most important object, and if there is water carriage, it greatly enhances the value of the farm. The roads to the fields, and the distance of these from the farm-yard; the convenience of having good pasture, or land easily laid down to grass, near the homestead, and especially the situation of the farm-buildings with respect to the land, and the abundance of good water, are all circumstances which must be well considered, and which greatly influence the probable profits, and consequently the rent which may be fairly offered. A central situation is no doubt the most advantageous for the farm-buildings, as greatly diminishing the labor in harvest, and in carrying out manure. But there may be circumstances which render some spot nearer the extremity of the land more eligible, and it is only when entirely new buildings are to be erected that there is a choice. The old farm-buildings are generally in low and sheltered situations, but it is a great inconvenience to have to carry the manure, which is the heaviest thing carted on a farm, up a steep hill. The best situation is on a moderate slope, neither in the lowest nor highest ground. This disposition of the buildings is of great importance both to the landlord and tenant.

Large straggling buildings are inconvenient, and cost much in repairs. The house should be neat and comfortable, fit for the residence of a farmer who has a capital such as the farm requires. The rooms should be airy and healthy, facing the south, with a neat garden in front of the house. The farm-yard should be to the north, behind it. Near the house, and the farm-yard, there should be a small paved court, separated from the yard by a low wall. In this court, which should communicate with the dairy, utensils may be placed on proper benches, to air and dry in the sun. The architecture of the buildings may be left to the taste of the proprietor or his architect. The simpler it is, the more appropriate. The yard or yards in a large farm should be sheltered on the north side by the barns, which need not be so extensive as used formerly to be thought necessary. If there is a thrashing machine, a single floor to thrash the seeds upon, and to employ the men occasionally in winter, is quite sufficient. Every farm which is so extensive as to require more than one floor to thrash the corn on, ought always to have a thrashing mill attached to it.

A small yard, distinct from the other, with sheds for the cattle to shelter themselves under, in wet and stormy weather, is a great advantage, and may be added at a trifling expense to any set of farm-buildings. The cart-sheds should be in the stack-yard, which properly occupies a space north of the barn. There should be a sufficient number of stands, with proper pillars and frames to build stacks on. Each stack should be of such a size as to be conveniently taken into the barn to be thrashed out. The round form, and the square which becomes nearly round when built up, are most convenient. Nine stone or cast-iron pillars, with caps over them, are placed on brick foundations, and support a strong frame on which the stack is built. In the centre of the stack there is usually a pyramidical open frame, to allow the air to circulate through the stack, and prevent the heating of the grain. On each side of the yard should be placed the stables, cow-houses, and feeding-stalls, with a pump of good water near the last, and convenient places to put hay, straw, and turnips in, with a machine to cut them. A great deal of time and labor is saved by a proper arrangement of the different parts of the farm-buildings. An underground cistern near the cow-house and stables, into which the urine and washings of the cow-house may run by means of a sink or drain, is a most useful appendage, which is too little thought of in England, whereas it is one of the most indispensable parts of a Flemish farm. It supplies a kind of manure, which can be applied to the land at all times, which invigorates sickly crops, and may often produce an abundant return, where otherwise there would be a complete failure.

In Scotland it is notorious that rents are much higher than in England, not only for small occupations, but for extensive farms; and that the tenants have complained less of the times than their neighbors in the south. It may be worth while to inquire into the cause of this, for the low price of corn must affect the Scotch farmer equally with the English. One great difference between the Scotch and the English farmer is, that the former gets work done at a cheaper rate than the latter. The Scotch laborer is fully as well fed, and clothed, and lodged, as the English; but he has less money to spend at the ale-house. He is paid, not in a certain sum every Saturday, but in comforts, in the keep of a cow, in a certain number of rows of potatoes, a certain quantity of malt to make his beer, a cottage to live in, and oatmeal to feed his family. His immediate wants are supplied, and he is comfortable; the consequence is, that he works willingly. He has no remnant of the last night's debauch at the beer-shop. He is early at work, and he does his work cheerfully. The horses of a Scotch farmer are well fed; they are always in good condition. They work 10 and even 12 hours in a day, at 2 yokings. The ploughman only thinks how he shall finish his work in proper time, and unless he makes the horses work as much as they can without distressing them, he knows he shall not get through his work. All this is worth 25 per cent. on the whole labor of the farm, as Arthur Young has very judiciously calculated, when he gives the expense of labor on the farm of a gentleman, compared with that on the land of a farmer who works with his men. The moral effect of an interest in the work to be done, when opposed to that of a perfectly distinct and often hostile interest, will readily account for so great a difference.

But besides this, the Scotch farmer has generally the advantage of a scientific education, and of a thorough knowledge of the principles of his profession; and with the shrewdness peculiar to his country, he knows how to take advantage of every favorable circumstance. He has also been taught to calculate, and will soon discover where there is a profit or a loss. This has made him turn his attention to cattle and sheep of late years, more than to the production of corn; and the Scotch have found that while a very decent profit was made on the cattle, their land produced more corn, although it sold at a lower price; for the green crops raised for the cattle, and the manure made by them, enriched the land so much, that the average produce on some light lands was nearly doubled. All this kept up rents to a much higher level than in England, where prices were low, and there were no means of diminishing expenses or increasing produce. Hence rents in Scotland have kept up wonderfully, when we consider the great fall of rents in England since the peace.

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ARCHIL. A violet red paste used in dyeing, of which the substance called *cudbear* in Scotland (from *Cuthbert*, its first preparer in that form), is a modification. Two kinds of archil are distinguished in commerce, the *archil* plant of the Canaries, and that of Auvergne. The first is most esteemed: it is prepared from the *lichen rocellus*, which grows on rocks adjoining the sea in the Canary and Cape de Verd Islands, in Sardinia, Minorca, &c., as well as on the rocks of Sweden. The second species is prepared from the *lichen parellus*, which grows on the basaltic rocks of Auvergne.

There are several other species of lichen which might be employed in producing an analogous dye, were they prepared, like the preceding, into the substance called *archil*. Hellot gives the following method for discovering if they possess this property. A little of the plant is to be put into a glass vessel; it is to be moistened with ammonia and lime-water in equal parts; a little muriate of ammonia (sal ammoniac) is added; and the small vessel is corked. If the plant be of a nature to afford a red dye, after three or four days, the small portion of liquid, which will run off on inclining the vessel, now opened, will be tinged of a crimson red, and the plant itself will have assumed this color. If the liquor or the plant does not take this color, nothing need be hoped for; and it is useless to attempt its preparation on the great scale. Lewis says, however, that he has tested in this way a great many mosses, and that most of them afforded him a yellow or reddish-brown color; but that he obtained from only a small number a liquor of a deep red, which communicated to cloth merely a yellowish-red color.

Prepared archil gives out its color very readily to water, ammonia, and alcohol. Its solution in alcohol is used for filling spirit-of-wine thermometers; and when these thermometers are well freed from air, the liquor loses its color in some years, as Abbé Nollet observed. The contact of air restores the color, which is destroyed anew, in vacuo, in process of time. The watery infusion loses its color, by the privation of air, in a few days; a singular phenomenon, which merits new researches.

The infusion of archil is of a crimson bordering on violet. As it contains ammonia, which has already modified its natural color, the fixed alkalies can produce little change on it, only deepening the color a little, and making it more violet. Alum forms in it a precipitate of a brown red; and the supernatant liquid retains a yellowish-red color. The solution of tin affords a reddish precipitate, which falls down slowly; the supernatant liquid retains a feeble red color. The other metallic salts produce precipitates which offer nothing remarkable.

The watery solution of archil, applied to cold marble, penetrates it, communicating a beautiful violet color, or a blue bordering on purple, which resists the air much longer than the archil colors applied to other substances. Dufay says, that he has seen marble tinged with this color preserve it without alteration at the end of two years.

To dye with archil, the quantity of this substance deemed necessary, according to the quantity of wool or stuff to be dyed, and according to the shade to which they are to be brought, is to be diffused in a bath of water as soon as it begins to grow warm. The bath is then heated till it be ready to boil, and the wool or stuff is passed through it without any other preparation, except keeping that longest in, which is to have the deepest shade. A fine gridelin, bordering upon violet, is thereby obtained; but this color has no permanence. Hence archil is rarely employed with any other view than to modify, heighten, and give lustre to the other colors. Hellot says, that having employed archil on wool boiled with tartar and alum, the color resisted the air no more than what had received no preparation. But he obtained from herb archil (*l'orseille d'herbe*) a much more durable color, by putting in the bath some solution of tin. The archil thereby loses its natural color, and assumes one approaching more or less to scarlet, according to the quantity of solution of tin employed. This process must be executed in nearly the same manner as that of scarlet, except that the dyeing may be performed in a single bath.

Archil is frequently had recourse to for varying the different shades and giving them lustre; hence it is used for violets, lilachs, mallows, and rosemary flowers. To obtain a deeper tone, as for the deep *soupes au vin*, sometimes a little alkali or milk of lime is mixed with it. The suites of this browning may also afford agates, rosemary flowers, and other delicate colors, which cannot be obtained so beautiful by other processes. Alum cannot be substituted for this purpose; it not only does not give this lustre, but it degrades the deep colors.

The herb-archil is preferable to the archil of Auvergne, from the greater bloom which it communicates to the colors, and from the larger quantity of coloring matter. It has, besides, the advantage of bearing ebullition. The latter, moreover, does not answer with alum, which destroys the color; but the herb archil has the inconvenience of dyeing in an irregular manner, unless attention be given to pass the cloth through hot water as soon as it comes out of the dye.

Archil alone is not used for dyeing silk, unless for lilachs; but silk is frequently passed through a bath of archil, either before dyeing it in other baths or after it has been dyed, in order to modify different colors, or to give them lustre. Examples of this will be given in treating of the compound colors. It is sufficient here to point out how white silks are passed through the archil bath. The same process is performed with a bath more or less charged with this color, for silks already dyed.

Archil, in a quantity proportioned to the color desired, is to be boiled in a copper. The clear liquid is to be run off quite hot from the archil bath, leaving the sediment at the bottom, into a tub of proper size, in which the silks, newly scoured with soap, are to be turned round on the skein-sticks with much exactness, till they have attained the wished-for shade. After this they must receive one beetling at the river.

Archil is in general a very useful ingredient in dyeing; but as it is rich in color, and communicates an alluring bloom, dyers are often tempted to abuse it, and to exceed the proportions that can add to the beauty without at the same time injuring in a dangerous manner the permanence of the colors. Nevertheless, the color obtained when solution of tin is employed, is less fugitive than without this addition: it is red, approaching to scarlet. Tin appears to be the only ingredient which can increase its durability. The solution of tin may be employed, not only in the dyeing bath, but for the preparation of the silk. In this case, by mixing the archil with other coloring substances, dyes may be obtained which have lustre with sufficient durability.

We have spoken of the color of the archil as if it were natural to it; but it is, really, due to an alkaline combination. The acids make it pass to red, either by saturating the alkali, or by substituting themselves for the alkali.

The lichen which produces archil is subjected to another preparation, to make turnsole (litmus). This article is made in Holland. The lichen comes from the Canary Islands, and also from Sweden. It is reduced to a fine powder by means of a mill, and a certain proportion of potash is mixed with it. The mixture is watered with urine, and allowed to suffer a species of fermentation. When this has arrived at a certain degree, carbonate of lime in powder is added, to give consistence and weight to the paste, which is afterwards reduced into small parallelopipeds that are carefully dried.

The latest researches on the lichens, as objects of manufacture, are those of Westring of Stockholm. He examined 150 species, among which he found several which might be rendered useful. He recommends that the coloring matter should be extracted in the places where they grow, which would save a vast expense in curing, package, carriage, and waste. He styles the coloring substance itself cutbear, persio, or turnsole; and distributes the lichens as follows:—1st. Those which, left to themselves, exposed to moderate heat and moisture, may be fixed without a mordant upon wool or silk; such are the L. *cinereus, æmatonta, ventosus, corallinus, westringii, saxatilis, conspassus, barbatus, plicatus, vulpinus*, &c.

2. Those which develop a coloring matter, fixable likewise without mordant, but which require boiling and a complicated preparation; such are the lichens *subcarneus, dillenii, farinaceus, jubatus, furfuraceus, pulmonareus, cornigatus, cocciferus, digitatus, ancialis, aduncus*, &c. Saltpetre or sea-salt is requisite to improve the lustre and fastness of the dye given by this group to silk.

3. Those which require a peculiar process to develop their color; such as those which become purple through the agency of stale urine or ammonia. Westring employed the following mode of testing:—He put three or four drachms of the dried and powdered lichen into a flask; moistened it with three or four measures of cold spring water; put the stuff to be dyed into the mixture, and left the flask in a cool place. Sometimes he added a little salt, saltpetre, quicklime, or sulphate of copper. If no color appeared, he then moistened the lichen with water containing one twentieth of sal ammoniac, and one tenth of quicklime, and set the mixture aside in a cool place from eight to fourteen days. There appeared in most cases a reddish or violet colored tint. Thus the *lichen cinereus* dyed silk a deep carmelite, and wool a light carmelite; the *l. physodes* gave a yellowish-gray; the *pustulatus*, a rose red; *sanguinarius*, gray; *tartareus*, found on the rocks of Norway, Scotland, and England, dyes a crimson-red. In Jutland, cutbear is made from it, by grinding the dry lichen, sifting it, then setting it to ferment in a close vessel with ammonia. The lichen must be of the third year's growth to yield an abundant dye; and that which grows near the sea is the best. It loses half its weight by drying. A single person may gather from twenty to thirty pounds a day in situations where it abounds. No less than 2,239,685 pounds were manufactured at Christiansand, Flekkefiort, and Fakrsund, in Norway, in the course of the six years prior to 1812. Since more solid dyes of the same shade have been invented, the archil has gone much into disuse. Federigo, of Florence, who revived its use at the beginning of the fourteenth century, made such an immense fortune by its preparation, that his family became one of the grandees of that city, under the name of Oricellarii, or Rucellarii. For more than a century Italy possessed the exclusive art of making archil, obtaining the lichens from the islands of the Mediterranean. According to an official report of 1831, Teneriffe furnished annually 500 quintals (cwts.) of lichen;

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the Canary Isles, 400; Fuerta Santura, 300; Lancerot, 300: Gomera, 300; Isle of Ferro, 800. This business belonged to the crown, and brought in a revenue of 1500 piastres. The farmers paid from 15 to 20 reals for the right to gether each quintal. At that time the quintal fetched in the London market 4*l.* sterling.

Archil is perhaps too much used in some cloth factories of England, to the discredit of our dyes. It is said, that by its aid one third of the indigo may be saved in the blue vat; but the color is so much the more perishable. The fine soft tint induced upon much of the black cloth by means of archil is also deceptive. One half-pound of cudbear will dye one pound of woolen cloth. A crimson red is obtained by adding to the decoction of archil a little salt of tin (muriate), and passing the cloth through the bath, after it has been prepared by a mordant of tin and tartar. It must be afterwards passed through hot water.

The lichens have been of late years subjects of a multitude of interesting but intricate chemical researches, and a number of new compounds have been produced, as *lecanorin*, from *lecanora*, and *variolaria*, with which colorless substance a purple red is formed by the action of ammonia and the air; also erythrine and erythryline from several sorts of lichens, especially parmeliar ocella and tartarean, which afford, when digested with ammonia, a bright red dye, but if treated with alcohol only a white granular precipitate, when the solution is slowly evaporated; orcine and orceine are somewhat analogous products, also crystallizable, which may be obtained from the *variolaria dealbata*, by decomposition of the lecanorine. It has a sweet nauseous taste, and melts into a colorless fluid, which may be distilled. It is soluble both in water and alcohol. Orceine by means of ammonia and air forms archil.

Dyeing with archil with the aid of oil has been patented by Mr. Lightfoot, on the same principle as has been so long used in the Turkey red cotton dye. He has also recourse to metallic and earthy bases, with what success I have not heard. Aluminated potash is likewise mentioned along with a great variety of other chemicals.

ARDENT SPIRIT. Alcohol of moderate strength.

AREOMETER OF BAUME′. This scale is much used by the French authors.

Specific Gravity Numbers corresponding with Baumé's Areometric Degrees.

Liquids denser than Water.						Less dense than Water.			
Degrees.	Specific gravity.	Degrees.	Specific gravity.	Degrees.	Specific gravity.	Degrees.	Specific gravity.	Degrees.	Specific gravity.
0	1·0000	26	1·2063	52	1·5200	10	1·0000	36	0·8488
1	1·0066	27	1·2160	53	1·5353	11	0·9932	37	0·8439
2	1·0133	28	1·2258	54	1·5510	12	0·9865	38	0·8391
3	1·0201	29	1·2358	55	1·5671	13	0·9799	39	0·8343
4	1·0270	30	1·2459	56	1·5833	14	0·9733	40	0,8295
5	1·0340	31	1·2562	57	1·6000	15	0·9669	41	0·8249
6	1·0411	32	1·2667	58	1·6170	16	0·9605	42	0·8202
7	1·0483	33	1·2773	59	1·6344	17	0·9542	43	0·8156
8	1·0556	34	1·2881	60	1·6522	18	0·9480	44	0·8111
9	1·0630	35	1·2992	61	1·6705	19	0·9420	45	0·8066
10	1·0704	36	1·3103	62	1·6889	20	0·9359	46	0·8022
11	1·0780	37	1·3217	63	1·7079	21	0·9300	47	0·7978
12	1·0857	38	1·3333	64	1·7273	22	0·9241	48	0·7935
13	1·0935	39	1·3451	65	1·7471	23	0·9183	49	0·7892
14	1·1014	40	1·3571	66	1·7674	24	0·9125	50	0·7849
15	1·1095	41	1·3694	67	1·7882	25	0·9068	51	0·7807
16	1·1176	42	1·3818	68	1·8095	26	0·9012	52	0·7766
17	1·1259	43	1·3945	69	1·8313	27	0·8957	53	0·7725
18	1·1343	44	1·4074	70	1·8537	28	0·8902	54	0·7684
19	1·1428	45	1·4206	71	1·8765	29	0·8848	55	0·7643
20	1·1515	46	1·4339	72	1·9000	30	0·8795	56	0·7604
21	1·1603	47	1·4476	73	1·9241	31	0·8742	57	0·7656
22	1·1692	48	1·4615	74	1·9487	32	0·8690	58	0·7526
23	1·1783	49	1·4758	75	1·9740	33	0·8639	59	0·7487
24	1·1875	50	1·4902	76	2·0000	34	0·8588	60	0·7449
25	1·1968	51	1·4951			35	0·8538	61	0·7411

ARGILLACEOUS EARTH. The earth of clay, called in chemistry alumina, because it is obtained in greatest purity from alum.

ARGOL. Crude *tartar*; which see.

ARMS. Weapons of war. See FIRE-ARMS for an account of this manufacture.

ARRACK. A kind of intoxicating beverage made in India, by distilling the fermented juice of the cocoa-nut, the palmyra tree, and rice in the husk.

ARROW ROOT. The root of the *maranta arundinacea*, a plant which grows in the West Indies, furnishes, by pounding in mortars and elutriation through sieves, a peculiar species of starch, commonly, but improperly called arrow root. It is reckoned more nourishing than the starch of wheat or potatoes, and is generally also freer from peculiar taste or flavor. The fresh root consists, according to Benzon, of 0·07 of volatile oil; 26 of starch (23 of which are obtained in the form of powder, while the other 3 must be extracted from the parenchyma in a paste by boiling water); 1·58 of vegetable albumen; 0·6 of a gummy extract; 0·25 of chloride of calcium; 6 of insoluble fibrine; and 65·6 of water.

This plant has been lately cultivated with great success, and its root manufactured in a superior manner, upon the Hopewell estate, in the island of St. Vincent. It grows there to the height of about 3 feet, and it sends down its tap roots from 12 to 18 inches into the ground. Its maturity is known by the flagging and falling down of the leaves, an event which takes place when the plant is from 10 to 12 months old. The roots being dug up with the hoe are transported to the washing-house, where they are thoroughly freed from all adhering earth, and next taken individually into the hand, and deprived by a knife of every portion of their skins, while every unsound part is cut away. This process must be performed with great nicety, for the cuticle contains a resinous matter, which imparts color and a disagreeable flavor to the fecula, which no subsequent treatment can remove. The skinned roots are thrown into a large cistern, with a perforated bottom, and there exposed to the action of a copious cascade of pure water, till this runs off quite unaltered. The cleansed roots are next put into the hopper of the mill, and are subjected to the powerful pressure of two pairs of polished rollers of hard brass; the lower pair of rollers being set much closer together than the upper. (See the accompanying figure.) The starchy matter is thus ground into a pulp which falls into the receiver placed beneath, and is thence transferred to large fixed copper cylinders, tinned inside, and perforated at the bottom with numerous minute orifices, like a kitchen drainer. Within these cylinders, wooden paddles are made to revolve with great velocity, by the power of a water-wheel, at the same time that a stream of pure water is admitted from above. The paddle arms beat out the fecula from the fibres and parenchyma of the pulp, and discharge it in the form of a milk through the perforated bottom of the cylinder. This starchy water runs along pipes, and then through strainers of fine muslin into large reservoirs, where, after the fecula has subsided, the supernatant water is drawn off, and fresh water being let on, the whole is agitated and left again to repose. This process of ablution is repeated till the water no longer acquires any thing from the fecula. Finally, all the deposits of fecula of the day's work are collected into one cistern, and, being covered and agitated with a fresh charge of water, are allowed to settle till next morning. The water being now let off the deposit is skimmed with palette knives of German silver, to remove any of the superficial parts, in the slightest degree colored; and only the lower, purer, and denser portion is prepared by drying for the market. The drying-house on the Hopewell estate is constructed like the hothouse of an English garden. But instead of plants, it contains about 4 dozen of drying pans made of copper, 7½ feet by 4½, and tinned inside. Each pan is supported on a carriage, having iron axles, with lignum vitæ wheels, like those of a railway carriage, and they run on rails. Immediately after sunrise, these carriages with their pans, covered with white gauze, to exclude dust and insects, are run out into the open air, but if rain be apprehended, they are run back under the glazed roof. In about 4 days the fecula is thoroughly dry and ready to be packed, with German silver shovels, into tins or American flour barrels, lined with paper attached with arrow root paste. The packages are never sent to this country in the hold of the ship, as their contents are easily tainted by noisome effluvia, of sugar, &c. By such a skilful series of operations, and by such precautions, the arrow root thus manufactured may vie with any similar preparation in the Bermudas or any other part of the world. I have found it, on analysis and trial, to be pure, powerful, and agreeable, and a most wholesome article of food.

Fig. 26. Plan of arrow root grinding-mill, and of 2 sets of copper cylinder washing-machines, with the connecting machinery for driving them; the washing agitator being driven from the connecting shaft with leathern belts. *Fig.* 27. End elvevation of arrow root mill, with wheels and pinions, disengaging lever, &c. *Fig.* 28. End elevation of copper washing-cylinders, with press-framing, &c. The washing-cylinders are 6½ feet long and 3½ in diameter. The mill-rollers are 3 feet long and 1 foot in diameter

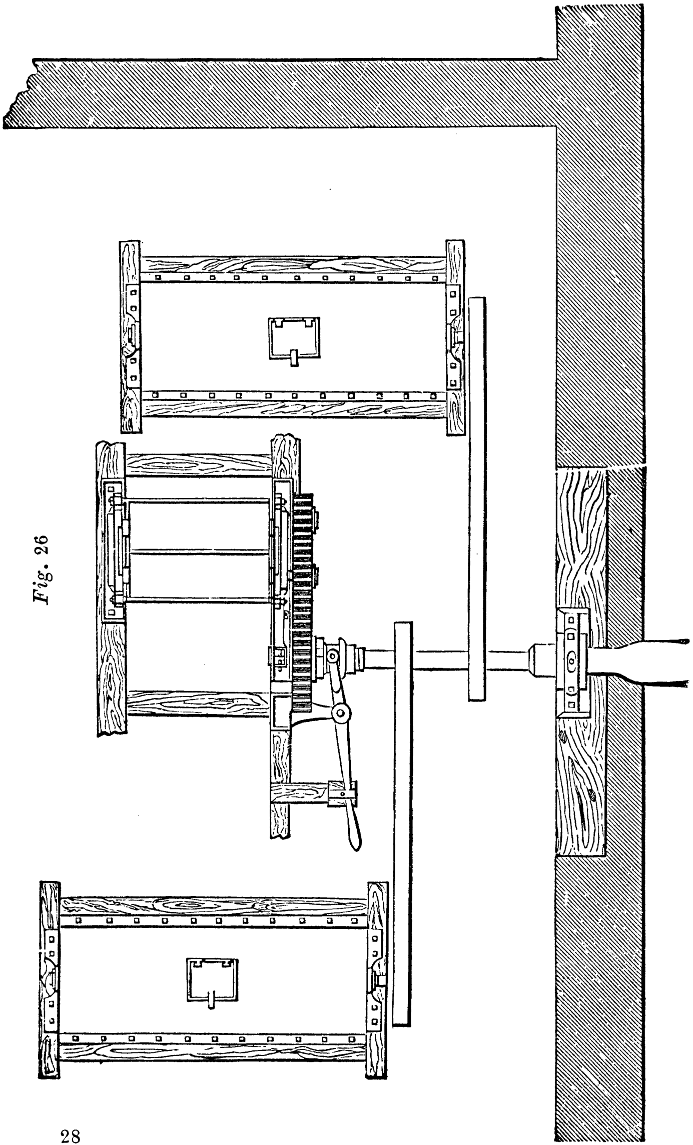

Fig. 26

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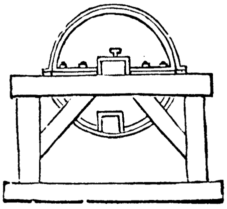

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The uses of arrow root are too well known and acknowledged to require recounting here. It is the most elegant and the richest of all the feculas, and being now manufactured, with the advantage of excellent machinery, and abundance of pure water, in the fertile island of St. Vincent, it may be brought into our market at a much more moderate price than it has heretofore been supplied from less favored localities. The Bermuda arrow root is treated necessarily with rain water collected in tanks, and therefore is occasionally soiled with insects, from which the St. Vincent article is entirely free.

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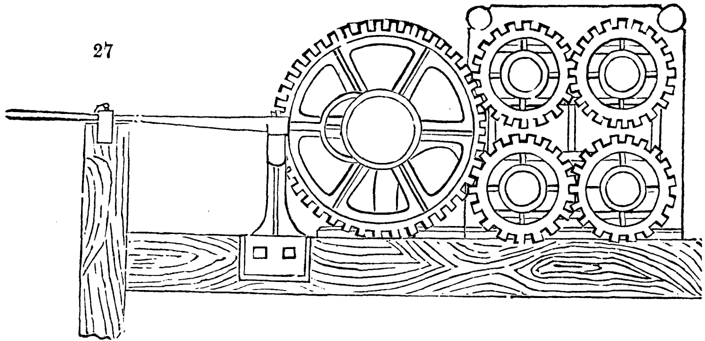

The presence of potato starch in arrow root may be discovered by the microscope. Arrow root consists of regular ovoid particles of nearly equal size, whereas potato starch consists of particles of an irregular ovoid or truncated form, exceedingly irregular in their dimensions, some being so large as $\frac{1}{300}$ of an inch, and others only $\frac{1}{2000}$. But the most convenient test is dilute nitric acid of 1·10 (about the strength of single aquafortis), which, when triturated in a mortar with the starch, forms immediately a transparent very viscid paste or jelly. Flour starch exhibits a like appearance. Arrow root, however, forms an opaque paste, and takes a much longer time to become viscid.

Arrow root may be distinguished from potato starch, not only by the different size of its particles, but by the difference of structure. Their surfaces in the arrow root are smooth, and free from the streaks and furrows seen in the potato particles by a good microscope. The arrow root, moreover, is destitute of that fetid unwholesome oil extractable by alcohol from potato starch.

Liebig places the powers of arrow root, as a nutriment to man, in a very remarkable point of view, when he states that 15 pounds of flesh contain no more carbon for supplying animal heat by its combustion into carbonic acid in the system than 4 pounds of starch; and that if a savage, with one animal and an equal weight of starch, could maintain life and health for a certain number of days, he would be compelled, if confined to flesh alone, in order to procure the carbon necessary for respiration during the same time, to consume five such animals.

		1841.	1842.	1843.	1844.
Quantities imported - - -	cwt.	—	7953	9236	10274
Quantities exported - - -	cwt.	—	334	264	200
Retained for consumption - -	cwt.	—	7561	8499	10018
Net revenue - -	£	1012	737	623	769

ARSENIC. This metal occurs native, in the state of oxide, and also combined with sulphur under the improper name of *yellow* and *red arsenic*, or orpiment and realgar. Arsenic is associated with a great many metallic ores; but it is chiefly extracted from those of cobalt, by roasting, in which case the white oxide of arsenic, or, more correctly, the arsenious acid is obtained. This acid is introduced occasionally in small quantities into the materials of flint glass, either before their fusion, or in the melting pot. It serves to peroxidize the iron oxide in the sand, and thereby to purify the body of the glass; but an excess of it makes the glass milky.

Scheele's green is a combination of this arsenious acid with oxide of copper, or an arsenite of copper, and is described under this metal.

Arseniate of potash is prepared, in the small way, by exposing to a moderate heat in a crucible a mixture of equal parts of white arsenic and nitre in powder. After fusion the crucible is to be cooled; the contents being dissolved in hot water, and the solution filtered, will afford regular crystals on cooling. According to M. Berzelius, they are composed of arsenic acid, 63·87; potash, 26·16; and water, 9·97. It is an acidulous salt, and is hence usually called the binarseniate, to denote that its composition is 2 atoms of arsenic acid, and 1 of potash. This article is prepared upon the great scale, in Saxony, by melting nitre and arsenious acid together in a cylinder of cast-iron. A neutral arseniate also is readily formed, by saturating the excess of acid in the above salt with potash; it does not crystallize. The acid arseniate is occasionally used in calico printing, for preventing certain points of the cotton cloth from taking on the mordant; with which view it is mixed up with gum water and pipe clay into a paste, which is applied to such places with a block.

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The extraction of arsenic from the cobalt ores, is performed at Altenberg and Reichenstein, in Silesia, with an apparatus, excellently contrived to protect the health of the smelters from the vapors of this most noxious metallic sublimate.

Figs. 29 to 32 represent the arsenical furnaces at Altenberg. *Fig.* 29 is a vertical section of the poison tower; *fig.* 30, a longitudinal section of the subliming furnace A, with the adjoining vault B, and the poison tower in part at *n; fig.* 31, the transverse section of the furnace A, of *fig.* 30; *fig.* 32, ground plan of the furnace A, where the left half shows the part above, and the right the part below the muffle or oblong retort; B′ is the upper view, B″ the ground plan of the vault B, of *fig.* 30; *m, n,* the base of the poison tower. In the several figures the same letters denote the same objects;

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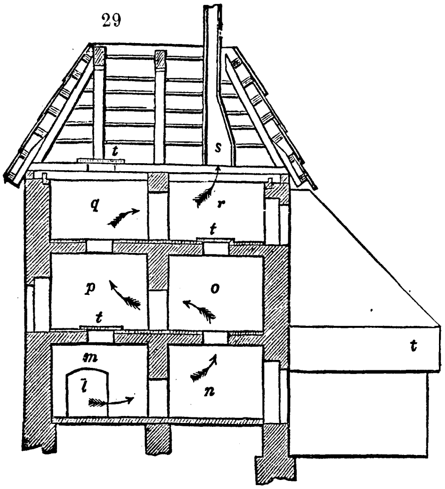

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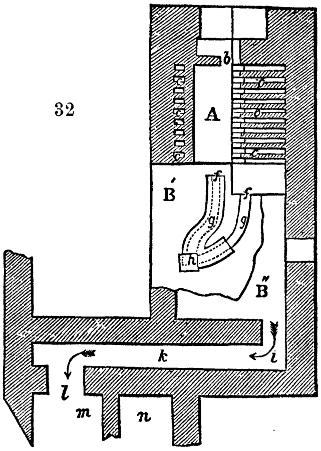

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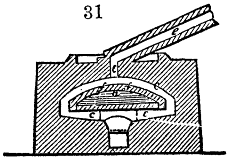

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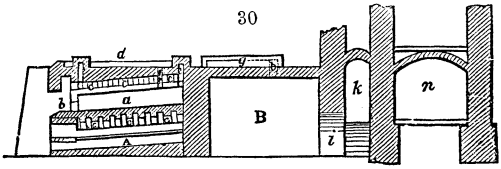

a is the muffle; *b* is its mouth for turning over the arsenical schlich, or ground ore; *c c c,* fire draughts or flues; *d,* an aperture for charging the muffle with fresh schlich; c, the smoke chimney; *f,* two channels or flues for the ascent of the arsenious fumes, which proceed to other two flues *g,* and then terminate both in *h,* which conducts the fumes into the vault B. They issue by the door *i,* into the conduit *k,* thence by *l* into the spaces *m, n, o, p, q, r,* of the tower. The incondensable gases escape by the chimney, *s.* The cover *t,* is removed after completion of the process, in order to push down the precipitate into the lower compartments.

The arsenious schlichs, to the amount of 9 or 10 cwt. for one operation (1 *roast-post,* or roasting round), are spread 2 or 3 inches thick upon the bottom of the muffle, heated with a brisk fire to redness, then with a gentler heat, in order to oxydize completely, before subliming, the arsenical ore. With this view the air must have free entrance, and the front aperture of the muffle must be left quite open. After 11 or 12 hours, the calcined materials are raked out by the mouth of the muffle, and fresh ones are introduced by the openings indicated above, which are closed during the sublimation.

The arsenious acid found in these passages is not marketable till it be re-sublimed in large iron pots, surmounted with a series of sheet iron drums or cast-iron cylinders, upon the sides of which the arsenic is condensed in its compact glassy form. The top cylinder is furnished with a pipe, which terminates in a condensing chamber.

Figs. 33, 34, represent the arsenic refining furnaces at Reichenstein. *Fig.* 33 shows

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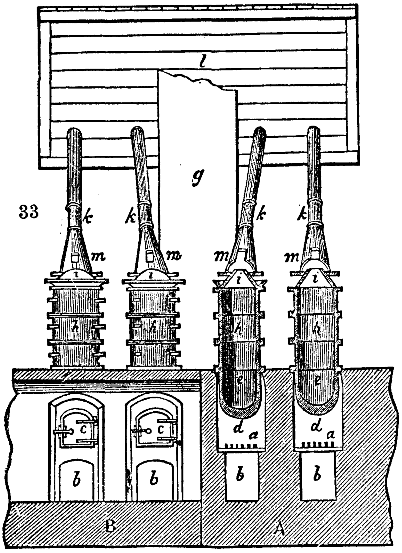

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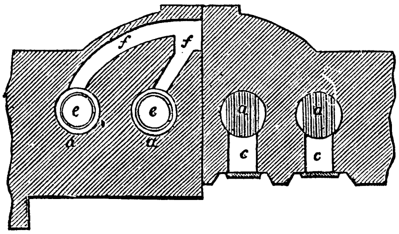

at A, a vertical section of the furnace, the kettle, and the surmounting drums or cylinders; over B it is seen in elevation; *fig* 34 is a ground plan of the four fireplaces. *a* is the grate; *b*, the ash-pit; *c*, the openings for firing; *d*, the fire-place; *e*, iron pots or kettles which are charged with the arsenious powder; *f*, the fire-flues proceeding to the common chimney *g; h*, iron cylinders; *i*, caps; *k*, pipes leading to the poison vent *l; m*, openings in the pipes for introducing the probing wires.

The conduct of the process is as follows:—The pot is filled nearly to its brim with 3½ cwt. of the arsenic meal, the cylinders are fitted on by means of their handles, and luted together with a mixture of loam, blood, and hair; then is applied first a gentle, and after half an hour, a strong fire, whereby the arsenic is raised partly in the form of a white dust, and partly in crystals; which, by the continuance of the heat, fuse together into a homogeneous mass. If the fire be too feeble, only a sublimate is obtained; but, if too violent, much of the arsenic is volatilized into the pipes. The workmen judge by the heat of the cylinders whether the operation be going on well or not. After 12 hours the furnace is allowed to cool, provided the probe wires show that the sublimation is over. The cylinders are then lifted off, and the arsenious glass is detached from their inner surface. According to the quality of the poison-flour, it yields from $\frac{3}{4}$ to $\frac{7}{8}$ of its weight of the glass or enamel. Should any dark particles of metallic arsenic be intermixed with the glass, a fresh sublimation must be had recourse to.

The following is the product in cwts. of arsenious acid, at Altenberg and Reichenstein, in Silesia, in the years

	1825.	1826.	1827.	1828.	1829.	1830.	1831.	1832.
White arsenic in a glassy state - - - -	2632	1703	2686	1900	2070	2961	3337	2730
Sublimed arsenic in powder - - - - -	-	27	33	31	30	44	69	38
Yellow arsenical glass -	112	11	56	-	86	313	60	219
Red arsenical glass -	3	-	-	-	28			

Arsenical Poison (*detection of*).—It is well known that fluids mixed with glutinous matter are very liable to froth up when hydrogen is disengaged in them from the mutual action of zinc and a dilute acid; and that the froth obstructs the due performance of the experiment of Marsh. It is equally known, that much of the arsenic contained in the poisonous liquid so tested escapes condensation and eludes measurement. A committee, appointed by the Prussian government, have contrived an ingenious modification of Marsh's apparatus, which I have simplified into the annexed form:—A is a narrow glass cylinder, open at top, about 10 inches high, and 1¼ or 1½ inch diameter inside; B is a glass tube, about 1 inch diameter outside, drawn to a point at bottom, and shut with a cork at top. Through the centre of this cork, the small tube C passes down air-tight, and is furnished at top with a stop-cock, into which the bent small tube of glass (without lead) E is cemented. The bent tube F is joined to the end of B with a collar of caoutchouc, or a perforated cork, which will be found more convenient.

The manner of using this apparatus is as follows:—Introduce a few oblong slips of zinc, free from arsenic, into B, and then insert its air-tight cock with

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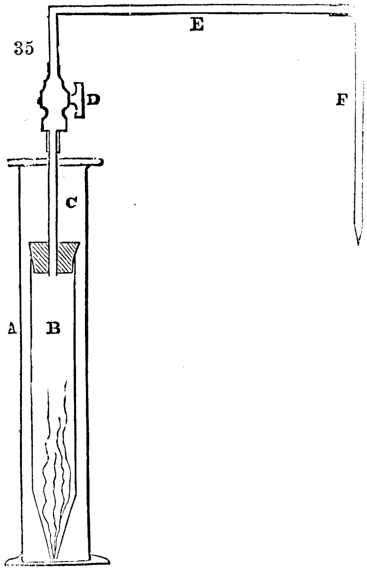

suspected liquid, acidulated with dilute hydrochloric or sulphuric acid (each pure) as will rise to the top of the cork, after B is full, and immediately shut the stop-cock. The generated hydrogen will force down the liquid out of the lower orifice of B into A, and raise the level of it above the cork. The extremity of the tube F being dipped beneath the surface of a weak solution of nitrate of silver, and a spirit-flame being placed a little to the left of the letter E, the stop-cock is then to be slightly opened, so that the gas which now fills the tube B may escape so slowly as to pass off in separate small bubbles through the silver solution. By this means the whole of the arsenic contained in the arseniuretted hydrogen will be deposited either in the metallic state upon the inside of the tube E, or with the silver into the characteristic black powder. The first charge of gas in B being expended, the stop-cock is to be shut, till the liquid be again expelled from it by a fresh disengagement of hydrogen. The ring of metallic arsenic deposited beyond E may be chased onwards by placing a second flame under it, and thereby formed into an oblong brilliant steel-like mirror. It is evident that by the patient use of this apparatus the whole arsenic in any poisonous liquid may be collected, weighed, and subjected to every kind of chemical verification. If F be joined to E by means of a perforated cork, it may readily be turned about, and its taper point raised into a position such as when the hydrogen issuing from it is kindled, the flame may be made to play upon a surface of glass or porcelain, in order to produce the arsenical mirror.

Or the preceding process may be made supplementary to that of boiling the arsenical foul liquor, acidulated with hydrochloric acid upon slips of clean copper, whereby the arsenic is precipitated upon the copper in a metallic film or thin crust more or less brilliant. If one of the slips of copper thus coated be placed in the tube B of the above described apparatus, it will give off its arsenic without the annoyance produced by the frothing up of a glutinous mixture.

Arsenic (*detection of*)—It is now generally known in this country, that towards the close of last year Professor Reinsch has proposed an entirely new method of detecting arsenic; which consists in acidulating any suspected fluid with hydrochloric acid, heating in it a thin plate of bright copper, upon which the arsenic is deposited in the form of a thin metallic crust, and then separating the arsenic from the copper in the state of oxide, by subjecting the copper to a low red heat in a glass tube. Organic fluids and solids, suspected to contain arsenic, may be prepared for this purpose by boiling them for half an hour with a little hydrychloric acid; solid matters being cut into small shreds, water being added in sufficient quantity to let the ebullition go on quietly, and care being taken to continue the boiling until the solids are either dissolved, as generally happens, or are reduced to a state of minute division.

Nothing can be more simple, easy or precise than the method of Reinsch. It is also exceedingly delicate, more so than is ever likely to be necessary in any medico-legal investigation; for it is adequate to detect a 250,000th part of arsenic in a fluid. It is also perfect in another respect: it does not leave any arsenic in the subject of analysis; none, at least, which can be detected by any other means, even by the most delicate process yet proposed, that of Mr. Marsh.

Cut the copper, on which the arsenic is deposited, into small chips, so that they may be easily packed in the bottom of a small glass tube, and apply a low red heat. A white crystalline powder sublimes; and if this be examined in the sunshine, or with a candle near it, a magnifier of four or five powers will enable the observer to distinguish the equilateral triangles composing the facets of the octahedral crystals, which are formed by arsenious acid when it sublimes. Sometimes the three equal angles, composing a corner of the octahedron, may be seen by turning the glass in various directions. If triangular facets cannot be distinguished, owing to the minuteness of the crystals, then shake out the copper chips, close the open end of the tube with the finger, and heat the sublimed powder over a very minute spirit lamp flame, chasing it up and down the tube till crystals of adequate size are formed. Next boil a little distilled water in the tube over the part where the crystalline powder is collected; and when the solution is cold divide it into three parts, to be tested with ammoniacal nitrate of silver, ammoniacal sulphate of copper, and sulphuretted hydrogen, either in the state of gas or dissolved in water.

In boiling organic substances in the weak hydrochloric acid care must be taken to ascertain that there is a decided excess of acid always present. Two fluidrachms to every 8 oz. of liquid are in general sufficient; but if the organic matter be an animal texture in a state of decay, a much larger quantity of acid may be necessary, owing to the presence of ammonia, which tends gradually to neutralize the acid as the solution goes on. Reinsch does not advise filtration of the fluid after the acid has acted sufficiently on the subject of analysis. But notwithstanding the delay occasioned by filtration, this seems to me advisable in most instances, otherwise organic particles are apt to attach themselves to the copper, and thus give rise to empyreuma, when the metallic arsenic is driven off by heat. The most convenient form for using the copper is that of copper leaf; but ordinary plates of copper may be easily made of any degree of fineness by immersing them for a time in dilute nitric acid. Where the quantity of arsenic in the fluid is supposed to be small, nearly half an hour should be allowed to elapse before the copper is removed. Before applying the sulphuretted hydrogen as a test to the solution of the sublimed oxide, the solution must be acidulated with hydrochloric or acetic acid. In every case the whole process should be applied in the first instance to distilled water, acidulated with the hydrochloric acid to be employed afterwards; and if the copper be tarnished, a purer acid must be obtained, or the copper must be subjected to the subsequent steps of the process, in order to ascertain whether the tarnishing be occasioned by arsenic or not.

Arsenical and Antimonial Spots (*distinguishing reactions of*).—If a drop of bromine is placed on a saucer, and a capsule containing arsenical spots inverted over it, the spots take a very bright lemon-yellow tinge in a short time. Antimonial spots, under the same circumstances, are acted on much more rapidly (in about five seconds at a temperature of 52° F.), and assume an orange shade. Both become colorless if exposed to the air, and are again restored if treated with a strong solution of sulphuretted hydrogen. The secondary yellow of the arsenical spots, as observed by Lassaigne, disappears on the addition of ammonia, whilst that of antimonial spots remains untouched. A concentrated solution of iodate of potash turns arsenical spots of a cinnamon-red, and dissolves them almost immediately. On antimonial spots it has no visible action within 3 or 4 hours. Solution of the hypochlorites (chlorides) of soda and lime and chlorine water dissolve arsenical spots instantaneously, leaving those of antimony. A concentrated solution of the chlorate of potash gradually acts upon arsenical spots, but not upon those of antimony. The nitroprusside of potassium, on the other hand, slowly dissolves antimony, producing no perceptible effect upon arsenic. The statement of Bischoff, that arsenical spots were soluble, antimonial insoluble, in a solution of the chloride of sodium, could not be verified, as, after repeated trials, it was found to leave both not perceptibly affected. The chloride of barium, the hydrochlorate and the sulphite of ammonia, afforded likewise no distinguishing action. The nitrate of ammonia dissolves arsenical more rapidly than antimonial stains. Of these reactions the most decisive are those of iodate of potash, hypochlorites of soda and lime, and fresh chlorine water.

Arsenic, Tin, and Antimony (*qualitative determination of*).—Although analytical chemistry possesses several methods of distinguishing between tin, antimony, and arsenic, I am not acquainted with any process by which these three metals, when they occur together, can be recognized with the same ease and quickness as in the case of most other metals. At the same time, the frequent occurrence of these three metals together renders a quick mode of detecting them highly desirable. The following may be viewed as a small contribution towards this object.

With regard to the discrimination of tin and antimony, this is founded on the solubility of metallic tin in strong muriatic acid, and the insolubility of antimonial stains, obtained according to Marsh's method in hypochlorite of soda.

When the muriatic solution of the two metals is treated with some metallic zinc, they are both precipitated, the antimony with disengagement of antimoniuretted hydrogen. When the precipitation is made in a small apparatus for the disengagement of hydrogen, the antimony is readily detected by the black stains insoluble in hypochlorite of soda, which it produces upon a piece of porcelain. When subsequently the precipitated metallic powder of tin and antimony is boiled with strong muriatic acid, only tin dissolves, forming protochloride, which, after subsequent dilution with water, is recognized by the brownish-black precipitate produced by sulphuretted hydrogen. Neither of these reactions are modified by the presence of arsenic.

The detection of arsenic when antimony is present, is founded upon a remarkable difference which these two metals exhibit towards nascent hydrogen when the latter is disengaged from an alkaline liquid. When a strong alkaline solution of antimony is heated with metallic zinc, antimony is precipitated simultaneously with a lively disengagement of pure hydrogen, which does not show the slightest reaction of antimoniuretted hydrogen. If, on the contrary, a substance containing arsenic acid is mixed with an excess of potash and some finely-divided zinc, the hydrogen given off on the application of heat is abundantly charged with arseniuretted hydrogen. The presence of this latter is ascertained most simply by holding a strip of paper dipped in nitrate of silver over the arseniferous mixture of potash and zinc; with the slightest trace of arsenic the paper is colored distinctly black.

ARTESIAN WELLS. Under this name is designated a cylindrical perforation, bored vertically down through one or more of the geological strata of the earth, till it passes into a porous gravel bed containing water, placed under such incumbent pressure as to make it mount up through the perforation, either to the surface or to a height convenient for the operation of a pump. In the first case, these wells are called spouting or overflowing. This property is not directly proportional to the depth, as might at first sight be supposed, but to the subjacent pressure upon the water. We do not know exactly the period at which the borer or sound was applied to the investigation of subterranean fountains, but we believe the first overflowing wells were made in the ancient French province of Artois, whence the name of Artesian. These wells, of such importance to agriculture and manufactures, and which cost nothing to keep them in condition, have been in use, undoubtedly, for several centuries in the northern departments of France, and the north of Italy; but it is not more than 50 or 60 years since they became known in England and Germany. There are now a great many such wells in London and its neighborhood, perforated through the immensely thick bed of the London clay, and even through some portions of the subjacent chalk. The boring of such wells has given much insight into the geological structure of many districts.

The formation of Artesian wells depends on two things, essentially distinct from each other: 1. On an acquaintance with the physical constitution, or nature, of the mineral structure of each particular country; and, 2. On the skilful direction of the processes by which we can reach the water level, and of those by which we can promote its ascent in the tube. We shall first treat of the best method of making the well, and then offer some general remarks on the other subjects.

The operations employed for penetrating the soil are entirely similar to those daily practised by the miner, in boring to find metallic veins; but the well excavator must resort to peculiar expedients to prevent the purer water, which comes from deep strata, mingling with the cruder waters of the alluvial beds near the surface of the ground, as also to prevent the small perforation getting eventually filled with rubbish.

The cause of overflowing wells has been ascribed to a variety of circumstances. But, as it is now generally admitted that the numerous springs which issue from the ground proceed from the infiltration of the waters progressively condensed in rain, dew, snow, &c. upon the surface of our globe, the theory of these interior streamlets becomes by no means intricate; being analogous to that of syphons and water jets, as expounded in the treatises on physics. The waters are diffused, after condensation, upon the surface of the soil, and percolate downwards, through the various pores and fissures of the geological strata, to be again united subterraneously in veins, rills, streamlets, or expanded films, of greater or less magnitude, or regularity. The beds traversed by numerous disjunctions will give occasion to numerous interior currents in all directions, which cannot be recovered, and brought to the day; but when the ground is composed of strata of sand, or gravel very permeable to water, separated by other strata nearly impervious to it, reservoirs are formed to our hand, from which an abundant supply of water may be spontaneously raised. In this case, as soon as the upper stratum is perforated, the waters may rise, in consequence of the hydrostatic pressure upon the lower strata, and even overflow the surface in a constant stream, provided the level from which they proceed be proportionally higher.

The sheets of water occur principally at the separation of two contiguous formations; and, if the succession of the geological strata be considered, this distribution of the water will be seen to be its necessary consequence. In fact, the lower beds are frequently composed of compact sandstone or limestone, and the upper beds of clay. In level countries, the formations being almost always in horizontal beds, the waters which feed the Artesian wells must come from districts somewhat remote, where the strata are more elevated, as towards the secondary and transition rocks. The copious streams condensed upon the sides of these colder lands may be therefore regarded as the proper reservoirs of our wells.

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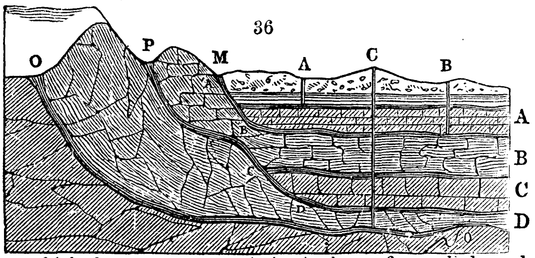
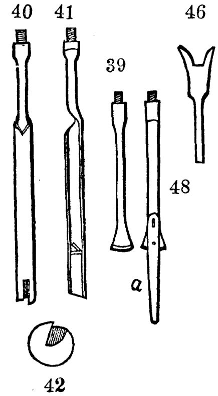
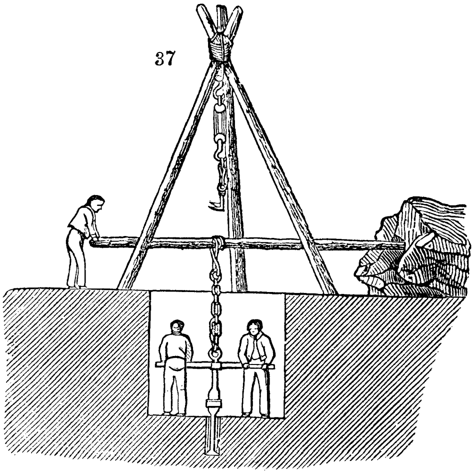


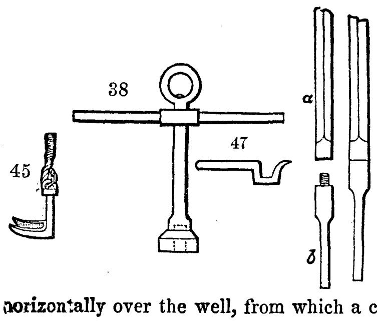
Fig. 36 represents the manner in which the condensed water of the heavens distributes itself under the surface of our globe. Here we have a geological section, showing the succession of the several formations, and the sheets or laminæ of water that exist at their boundaries, as well as in their sandy beds. The figure shows also very plainly that the height to which the water reascends in the bore of a well depends upon the height of the reservoir which supplies the sheet of water to which the well is perforated. Thus the well A, having gone down to the aqueous expanse *a a*, whose waters of supply are derived from the percolation M, will afford rising waters, which will come to the surface; while in the well B, supplied by the sheet P, the waters will spout above the surface, and in the well C they will remain short of it. The same figure shows that these wells often traverse sheets of water, which rise to different heights. Thus, in the well C there are five columns of ascending waters, which rise to heights proportional to the points whence they take their origin. Several of these will be spouting or overflowing, but some will remain beneath the surface.

The situation of the intended well being determined upon, a circular hole is generally dug in the ground, about 6 or 8 feet deep, and 5 or 6 feet wide. In the centre of this hole the boring is carried on by two workmen below, assisted by a laborer above, as shown in *fig.* 37.

The handle (*fig.* 38) having a female screw in the bottom of its iron shank, with a wooden bar or rail passing through the socket of the shank, and a ring at top, is the general agent to which all the boring implements are to be attached. A chisel (*fig.* 39) is first employed, and connected to this handle by its screw at top. If the ground is tolerably soft, the weight of the two workmen bearing upon the cross bar, and occasionally forcing it round, will soon cause the chisel to penetrate; but if the ground is hard or strong, the workmen strike the chisel down with repeated blows, so as to peck their way, often changing their situation by walking round, which breaks the stones, or other hard substances, that may happen to obstruct its progress.







The labor is very considerably reduced by means of an elastic wooden pole, placed horizontally over the well, from which a chain is brought down, and attached to the ring of the handle. This pole is usually made fast at one end, as a fulcrum, by being set into a heap of heavy loose stones; at the other end the laborer above gives it a slight up and down vibrating motion, corresponding to the beating motion of the workmen below, by which means the elasticity of the pole in rising lifts the handle and pecker, and thereby very considerably diminishes the labor of the workmen. See *fig.* 37.

When the hole has been thus opened by a chisel, as far as its strength would permit, the chisel is withdrawn, and a sort of cylindrical auger (*fig.* 40) attached to the handle (*fig.* 38), for the purpose of drawing up the dirt or broken stones which have been disturbed by the chisel. A section of this auger is shown in *fig.* 41, by which the internal valve will be seen. The auger being introduced into the hole and turned round by the workmen, the dirt or broken stones will pass through the aperture at bottom (shown at *fig.* 42), and fill the cylinder, which is then drawn up, and discharged at the top of the auger, the valve preventing its escape at bottom.

In order to penetrate deeper into the ground, an iron rod, as *a*, *fig.* 43, is now to be attached to the chisel, *fig.* 39, by screwing on to its upper end, and the rod is also fastened to the handle, *fig.* 38, by screwing into its socket. The chisel having thus become lengthened by the addition of the rod, it is again introduced into the hole; and the operation of pecking or forcing it down, is carried on by the workmen as before. When the ground has been thus perforated, as far as the chisel and its rod will reach, they must be withdrawn, in order again to introduce the auger, *fig.* 40, to collect and bring up the rubbish; which is done by attaching it to the iron rod, in place of the chisel. Thus, as the hole becomes deepened, other lengths of iron rods are added, by connecting them together, as *a b* are in *fig.* 44. The necessity of frequently withdrawing the rods from the holes, in order to collect the mud, stones, or rubbish, and the great friction produced by the rubbing of the tools against its sides, as well as the lengths of rods augmenting in the progress of the operation, sometimes to the extent of several hundred feet, render it extremely inconvenient, if not impossible, to raise them by hand. A tripedal standard is therefore generally constructed by three scaffolding poles tied together, over the hole, as shown *fig.* 37, from the centre of which a wheel and axle, or a pair of pully blocks is suspended, for the purpose of hauling up the rods, and from which hangs the fork, *fig.* 45. This fork is to be brought down under the shoulder, near the top of each rod, and made fast to it by passing a pin through two little holes in the claws. The rods are thus drawn up, about seven feet at a time, which is the usual distance between each joint, and at every haul a fork, *fig.* 46, is laid horizontally over the hole, with the shoulders of the lower rod resting between its claws, by which means the rods are prevented from sinking down into the hole again, while the upper length is unscrewed and removed. In attaching and detaching these lengths of rod, a wrench, *fig.* 47, is employed, by which they are turned round, and the screws forced up to their firm bearing.

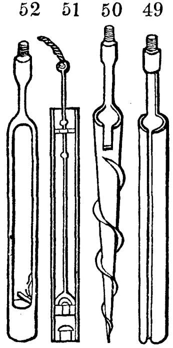
The boring is sometimes performed for the first sixty or a hundred feet, by a chisel of 2½ inches wide, and cleared out by a gouge of 2¼ diameter, and then the hole is widened by a tool, such as is shown at *fig.* 48. This is merely a chisel, as *fig.* 39, four inches wide, but with a guide, *a*, put on at its lower part, for the purpose of keeping it in a perpendicular direction; the lower part is not intended to peck, put to pass down the hole previously made, while the sides of the chisel operate in enlarging the hole to four inches. The process, however, is generally performed at one operation, by a chisel of four inches wide, as *fig.* 39, and a gouge of three inches and three quarters, as *fig.* 40.

It is obvious that placing and displacing the lengths of rod, which is done every time that the auger is required to be introduced or withdrawn, must, of itself, be extremely troublesome, independent of the labor of boring, but yet the operation proceeds, when no unpropitious circumstances attend it, with a facility almost incredible. Sometimes, however, rocks intercept the way, which require great labor to penetrate; but this is always effected by pecking, which slowly pulverizes the stone. The most unpleasant circumstance attendant upon this business is the occasional breaking of a rod into the hole, which sometimes creates a delay of many days, and an incalculable labor in drawing up the lower portion.

When the water is obtained in such quantities and of such quality as may be required, the hole is dressed or finished by passing down it a diamond chisel, funnel mouthed, with a triangular bit in its centre; this makes the sides smooth previous to putting in the pipe. This chisel is attached to rods, and to the handle, as before described; and, in its descent, the workmen continually walk round, by which the hole is made smooth and cylindrical. In the progress of the boring, frequent veins of water are passed through; but, as these are small streams, and perhaps impregnated with mineral substances, the operation is carried on until an aperture is made into a main spring, which will flow up to the surface of the earth. This must, of course, depend upon the level of its source, which, if in a neighboring hill, will frequently cause the water to rise up, and produce a continued fountain. But if the altitude of the distant spring happens to be below the level of the surface of the ground where the boring is effected, it sometimes happens that a well of considerable capacity is obliged to be dug down to that level, in order to form a reservoir, into which the water may flow, and whence it must be raised by a pump; while, in the former instance, a perpetual fountain may be obtained. Hence, it will always be a matter of doubt, in level countries, whether water can be procured which would flow near to or over the surface; if this cannot be effected, the process of boring will be of little or no advantage, except as an experiment to ascertain the fact.

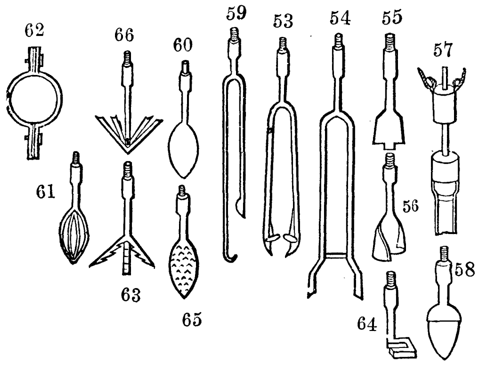
In order to keep the strata pure and uncontaminated with mineral springs, the hole is cased, for a considerable depth, with a metallic pipe, about a quarter of an inch smaller than the bore. This is generally made of tin (though sometimes of copper or lead) in convenient lengths; and, as each length is let down, it is held by a shoulder resting in a fork, while another length is soldered to it; by which means a continuous pipe is carried through the bore, as far as may be found necessary, to exclude land springs, and to prevent loose earth or sand from falling in, and choking the aperture.

Mr. John Good, of Tottenham, who had been extensively employed in boring the earth for water, obtained a patent, in Aug. 1823, for certain improved implements contrived by him to facilitate his useful labors; a description of which cannot fail to be interesting.



The figures annexed exhibit these ingenious tools; *fig.* 49 is an auger, to be connected by the screw-head to the length of rods by which the boring is carried on. This auger is for boring in soft clay or sand; it is cylindrical, and has a slit or opening from end to end, and a bit, or cutting-piece at bottom. When the earth is loose or wet, an auger of the same form is to be employed, but the slit or opening reduced in width, or even without a slit or opening. A similar auger is used for cutting through chalk; but the point or bit at bottom should then project lower, and, for that purpose, some of these cylindrical augers are made with moveable bits, to be attached by screws, which is extremely desirable in grinding them to cutting edges. *Fig.* 50 is a hollow conical auger, for boring loose sandy soils; it has a spiral cutting edge coiled round it, which, as it turns, causes the loose soil to ascend up the inclined plane, and deposite itself in the hollow within. *Fig.* 51 is a hollow cylinder or tube, shown in section, with a foot-valve, and a bucket to be raised by a rod and cord attached at the top; this is a pumping tool, for the purpose of getting up water and sand that would not rise by the auger. When this cylinder is lowered to the bottom of the bore, the bucket is lifted up by the rod and cord, and descends again by its own gravity, having a valve in the bucket, opening upwards, like other lift pumps; which, at every stroke, raises a quantity of water and sand in the cylinder equal to the stroke; the ascent and descent of the bucket being limited by a guide-piece at the top of the cylinder, and two small knobs upon the rod which stop against the cross-guide. *Fig.* 52 is a tool for getting up broken rods. It consists of a small cylindrical piece at bottom, which the broken rod slips through when it is lowered, and a small catch with a knife-edge, acted upon by a back-spring. In rising, the tool takes hold of the broken rod, and thereby enables the workman at top to draw it up. Another tool for the same purpose, is shown at *fig.* 53, which is like a pair of tongs; it is intended to be slidden down the bore, and for the broken rod to pass between the two catches, which, pressed by back-springs, will, when drawn up, take fast hold of the broken rod.

Fig. 54 is a tool for widening the hole, to be connected, like all the others, to the end of the length of rods passed down the bore; this tool has two cutting-pieces extending on the sides at bottom, by which, as the tool is turned round in the bore, the earth is peeled away. *Fig.* 55 is a chisel, or punch, with a projecting piece to be used for penetrating through stone; this chisel is, by rising and falling, made to peck the stone, and pulverize it; the small middle part breaking it away first, and afterwards the broad part coming into action. *Fig.* 56 is another chisel, or punching tool, twisted on its cutting edge, which breaks away a greater portion of the stone as it beats against it.



The manner of forcing down lengths of cast-iron pipe, after the bore is formed, is shown at *fig.* 57; the pipe is seen below in the socket, at the end of which a block is inserted; and from this block a rod extends upwards, upon which a weight at top slides. To this weight cords are shown to be attached, reaching to the top of the bore; where the workmen alternately raise the weight and let it fall, which, by striking upon the block in its middle, beats down the pipe by a succession of strokes; and when one length of pipe has, by these means, been forced down, another length is introduced into the socket of the former. Another tool for the same purpose is shown at *fig.* 58, which is formed like an acorn; the raised part of the acorn strikes against the edge of the pipe, and by that means, it is forced down the bore. When it happens that an auger breaks in the hole, a tool similar to that shown at *fig.* 59 is introduced; on one side of this tool a curved piece is attached, for the purpose of a guide, to conduct it past the cylindrical auger; and at the end of the other side is a hook, which, taking hold of the bottom edge of the auger, enables it to be drawn up.

Wrought iron, copper, tin, and lead pipes, are occasionally used for lining the bore; and as these are subject to bends and bruises, it is necessary to introduce tools for the purpose of straightening their sides. One of these tools is shown at *fig.* 60, which is a bow, and is to be passed down the inside of the pipe, in order to press out any dents. Another tool, for the same purpose, is shown at *fig.* 61, which is a double bow, and may be turned round in the pipe for the purpose of straightening it all the way down; at *fig.* 62, is a pair of clams, for turning the pipe round in the hole while driving.

When loose stones lie at the bottom of the hole, which are too large to be brought up by the cylindrical auger, and cannot be conveniently broken, then it is proposed to introduce a triangular claw, as *fig.* 63, the internal notches of which take hold of the stone, and as the tool rises, bring it up. For raising broken rods, a tool like *fig.* 64 is sometimes employed, which has an angular claw that slips under the shoulder of the rod, and holds it fast while drawing up.

In raising pipes it is necessary to introduce a tool into the inside of the pipe, by which it will be held fast. *Fig.* 65 is a pine-apple-tool for this purpose; its surface is cut like a rasp, which passes easily down into the pipe, but catches as it is drawn up; and by that means brings the pipe with it. *Fig.* 66 is a spear for the same purpose, which easily enters the pipe by springing; at the ends of its prongs there are forks which stick into the metal as it is drawn up, and thereby raise it.

These are the new implements, for which the patent was granted. In the process of boring, there does not appear to be anything new proposed; but that these several tools are to be employed for boring, packing, and otherwise penetrating, raising the earth, and extracting broken or injured tools. There are also suggestions for employing long buckets, with valves opening upward in their bottoms, for the purpose of drawing water from these wells when the water will not flow over the surface; also lift pumps, with a succession of buckets for the same purpose. But as these suggestions possess little if any novelty, it cannot be intended to claim them as parts of the patent.

The older geological formations are seldom propitious to the construction of Artesian wells, on account of the compact massiveness of their rocks, of the few fissures or porous places in them, and of the rarity of filtering strata overlying retentive ones. It is therefore vain to attempt the formation of an overflowing spring, upon the above principles, in territories of granite, gneiss, mountain limestone, and basalt. Among transition and secondary formations, such wells will rarely furnish a supply of good water. The latter strata of alternating clay and variegated sandstone contain so much gypsum and rock salt as to impregnate therewith the waters derived from them to an unpalatable degree. It is in the sandy, calcareous, and argillaceous strata of the Jura limestone, indeed, that borings may most probably be made for brine springs. The hot springs which burst out of the ground in primitive rocky districts come undoubtedly from a great depth under the surface, and derive their temperature, and also probably their waters, from the vapors of deep-seated volcanoes in connexion with the sea. A miniature representation of such springs is exhibited in the intermitting fountains of fresh water on the shoulder of Vesuvius. Springs of this kind, which vary with the seasons, may derive a portion of their water from the surface of the earth, from which it may sink through clefts in the primitive rocks, till meeting in its descent with stony obstructions and ascending steam, it is forced to remount in a heated state to the day, like the Geisers in Iceland. The most remarkable example of an Artesian well is that recently formed at Grenelle, a suburb at the southwest of Paris, where there was a great want of water. It cost eight years of difficult labor to perforate. The geological strata round the French capital are all of the tertiary class, and constitute a basin, like that shown in *fig.* 67 The bottom of this basin is chalk; A A are tertiary strata above the chalk; B B, chalk or cretaceous carbonate of lime; C C, D D, green sand and clay; E E, oolite and Jura limestone (*muschelkalk*); E A, general slope of the surface of the country from Langres to Paris; M A, the level of the sea. Over a circular space, of which Paris is the centre,

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and which is bounded by the towns of Laon, Mantes, Blois, Sancerre, Nogent-sur Seine, and Epernay, these strata are found upon the surface, concealing the chalk; but on the other side of these towns, the edge of the basin being passed, the chalk is generally the superficial bed. By looking at the order of these tertiary strata, it is easy to perceive the obstacles that M. Malot, the engineer of the well, had to overcome, and the difficulty and hazard of his undertaking. The surface at Grenelle consists of gravel, pebbles, and fragments of rock, which have been deposited by the waters at some period anterior to any historical record. Below this layer of detritus, it was known to the engineer, by geological induction, as well as previous experience, that at Grenelle marl and clay would be found, instead of the limestone which generally forms the immediately subjacent stratum. He was aware that he had to bore about 440 yards! deep before he should arrive at the sheet of water (see *figure*) which flows in the gravel below the limestone, and supplies the wells of St. Ouen, St. Denis, and Stains. Underneath the marl and the clay, the boring rods had to perforate pure gravel, plastic clay, and finally chalk, which forms the bottom of the general tertiary basin, as we have seen. No calculation from geological data could determine the thickness of this stratum of chalk, which, from its powers of resistance, might present an almost insuperable obstacle. The experience acquired in boring the wells of Elbeuf, Rouen, and Tours, was in this respect but a very imperfect guide. But supposing this obstacle to be overcome, was he sure of finding a supply of water below this mass of chalk? In the first place, the strata C D below the chalk possessed, as we shall see, all the necessary conditions for producing Artesian springs, namely, successive layers of clay and gravel, or of pervious and impervious beds. M. Malot confidently relied on his former experience of the borings of the wells at Rouen, Elbeuf, and Tours, where abundant supplies of water had been found below the chalk, between similar strata of clay and gravel.

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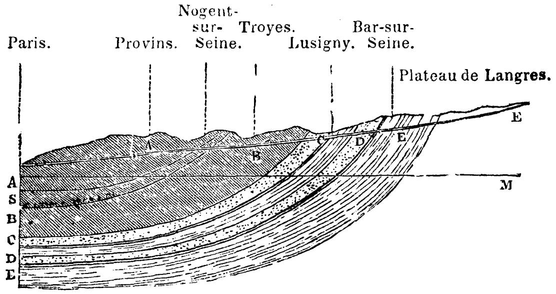

But one other condition is requisite to insure the rising of the water in an Artesian well, namely, that the feeding level of infiltration should be higher than the orifice in the bore above which the water is to ascend. This, however, turned out to be the case with Grenelle. M. Arago had shown that the water of the spring here would necessarily rise to the surface, because in the well at Elbeuf, which is nearly 9 yards above the level of the sea, the water rises from 27 to 29 yards above the surface of the earth, and, consequently, from 36 to 38 yards above the ocean level. Now, as the orifice of the bore at Grenelle is only 34 yards above the same level, it follows that, if the identical spring be met with, the water must rise above the earth's surface at Grenelle.

The necessary works were commenced with boring-rods about 9 yards long, attached to each other, and which could be raised or lowered by mechanical power, while an ingenious method was adopted for giving them a rotary motion. The diameter of the bore was about 6 inches. The instrument affixed to the end of the lowest boring-rod was changed according to the different strata which were successively attacked; the form suited for passing through the softer materials near the surface being unsuitable for boring through the chalk and flint, a hollow tube was used for the former, while a chisel-shaped tool was employed to penetrate the latter. The size of the rods was lessened as the depth increased; and, since the subterranean water was not reached so soon as was expected, it became requisite to enlarge five several times the diameter of the bore, in order to permit the work to be successfully prosecuted. Accidents occurred which tried the patience of the projectors. In May, 1837, when the boring had extended down to a depth of 418 yards, the hollow tube, with nearly 90 yards of the long rods attached to it, broke and fell to the bottom of the hole, whence it became necessary to extract the broken parts before any further progress could be made. The difficulty of accomplishing this task may be conceived; for the different fragments were not all extracted until after the constant labor of 15 months. Again, in April, 1840, in passing through the chalk, the chisel attached to the boring-rod got detached

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and before it could be recovered, several months were spent in digging round about it. A similar occurrence created an obstacle which impeded the work for 3 months, but, instead of withdrawing the detached part, it was forcibly driven down among the stratum of gravel. At length, in February, 1841, after eight years' labor, the rods suddenly descended several yards, having pierced into the vault of the subterranean water so long sought after by the indefatigable engineer. A few hours afterwards he was rewarded for all his anxious toils; for lo! the water rose to the surface, and discharged itself at the rate of 600,000 gallons per hour!

The depth reached down was 602 yards, or about three times the height of St. Paul's. The pipe by which the water reaches the surface has been recently carried to a height nearly level with the source of supply. The portion of the pipe above the ground is surrounded with a monumental pagoda of ornamental carpentry, and it discharges a circular cascade of clear water continually into a circular iron reservoir, to be thence conveyed by a lateral pipe to the ground. The water is well adapted for all domestic uses, and it will be unfailing, being supplied from the infiltration of a surface of country nearly 200 miles in diameter. The Artesian wells of Elbeuf, Rouen, and Tours, which were formed many years ago, overflow in never-varying streams; and the ancient Artesian well at Lillers, in the Pas de Calais, has for about seven centuries furnished a constant and equable supply.

The opportunity of ascertaining the temperature of the earth at different depths was not neglected during the progress of the works at Grenelle. Thermometers placed at a depth of 30 yards in the wells of the Paris Observatory invariably stand at 53° Fahrenheit. In the well at Grenelle the thermometer indicated 74° Fahr. at a depth of 442 yards, and at 550 yards it stood at 79°. At the depth finally arrived at of 602 yards, the temperature of the water which rose to the surface was 81°, corroborating previous calculations on the subject. For a descent of 572 yards there is an increase of temperature equal to 28° F., which is 20·4 yards, or 61·2 feet for each degree of that scale. Now that the skilful labor of so many years is terminated, the Parisians regret that the subterranean sheet of water had not lain 1000 yards beneath the surface, that they might have had an overflowing stream of water at 104°, to furnish a cheap supply to their numerous hot-bath establishments.

In boring Artesian wells through stratified formations, several sheets of water are met with at successive heights; as at St. Ouen there are 5, each capable of rising: one of these is at 36 metres of depth; a second at 45½m., a third at 51½m., a fourth at 59·30m., and a fifth at 66½m. At Tours there are 3 sheets susceptible of mounting, at 95, 102, and 125 metres respectively beneath the surface. Seven large sheets of fresh water were in like manner observed in boring for coal near Dieppe. The deepest sheets, having the greatest superincumbent pressure, in general give the highest hydrostatic level. The quantity of water furnished by such wells seems to be nearly constant: thus the well of Grenelle, near Paris, continues to deliver 3000 litres per minute at the surface of the ground; the well of Bages, near Perpignan, 2000 litres; that at Tours, 1110 at 2 metres above the level of the ground. It is said that some of the Artesian wells in and round about London do not deliver so much water as they formerly did; a deficiency ascribed to the vast quantities which have been drawn up from the lower sheets of water by the multitude of steam engines employed in pumping. When a copious flow of water from a deep well can be commanded, it may be used for driving water wheels with great advantage, since, from its elevated temperature, it is not liable to freeze; and for the same reason it is made to maintain a mild temperature by circulating in pipes through the interior of factories.

ASHES; said of crude potash, which is in fact obtained from the ashes of plants.

ASHES OF PLANTS; see AGRICULTURE.

ASHES, PEARL AND POT, see POTASH.

ASPARAGINE; a crystallizable product extracted from asparagus, consisting of 32·35 carbon, 18·73 azote, 6·60 hydrogen, and 42·32 oxygen. It is most easily procured from the roots of marsh-mallows. It is a curious substance, but hitherto has been applied to no use.

ASPHALTIC PAVEMENT; see BITUMEN.

ASPHALTUM. Native bitumen, so called from the lake Asphaltites.

ASSAY and ASSAYING. (*Coupellation*, Fr.; *Abtreiben auf der capelle*, Germ.) This is the process by which the quality of gold and silver bullion, coin, plate, or trinkets, is ascertained with precision.

The art of assaying gold and silver *by the cupel* is founded upon the feeble affinity which these metals have for oxygen, in comparison with copper, tin, and the other cheaper metals; and on the tendency which the latter metals have to oxidize rapidly in contact with lead at a high temperature, and sink with it into any porous, earthy vessel in a thin, glassy, or vitriform state. The porous vessel may be made either of wood-ashes, freed from their soluble matter by washing with water; or, preferably, of burned bones reduced to a fine powder.

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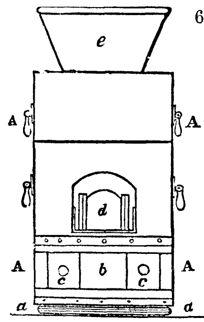
Alloy.		Lead for 1 of Alloy.	Ratio of the Copper to the Lead.
Silver.	Copper.		
1000	0	$\frac{3}{10}$	0
950	50	3	1 : 60
900	100	7	1 : 70
800	200	10	1 : 50
700	300	12	1 : 40
600	400	14	1 : 35
500	500	16 or 17	1 : 32
400	600	16 — 17	1 : 26·7
300	700	16 — 17	1 : 22·9
200	800	16 — 17	1 : 20
100	900	16 — 17	1 : 17·8
0	1000	16 — 17	1 : 16

Bismuth may be used as a substitute for lead in cupellation; two parts of it being nearly equivalent to three of lead. But its higher prices will prevent its general introduction among assay masters.

We begin this assay process by weighing, in a delicate balance, a certain weight of the metallic alloy; a gramme (=15·444 gr.) is usually taken in France, and 12 grains in this country. This weight is wrapped up in a slip of lead foil or paper, should it consist of several fragments. This small parcel, thus enveloped, is then laid in a watch glass or a capsule of copper, and there is added to it the proportion of lead suited to the quality of alloy to be assayed; there being less lead, the finer the silver is presumed to be. Those who are much in the habit of cupellation can make good guesses in this way; though it is still guess work, and often leads to considerable error, for if too much lead be used for the proportion of baser metal present, a portion of the silver is wasted; but if too little, then the whole of the copper, &c. is not carried off, and the button of fine silver remains more or less impure. The most expert and experienced assayer by the cupel, produces merely a series of approximate conjectural results which fall short of chemical demonstration and certainty in every instance. The lead must be, in all cases, entirely free from silver, being such as has been revived from pure litharge; otherwise errors of the most serious kind would be occasioned in the assays.

The best cupels weigh 12½ grammes, or 193 grains. The cupels allow the fused oxydes to flow through them as through a fine sieve, but are impermeable to the particles of metals; and thus the former pass readily down into their substance while the latter remain upon their surface; a phenomenon owing to the circumstance of the glassy oxydes moistening, as it were, the bone-ash powder, whereas the metals can contract no adherence with it. Hence also the liquid metals preserve a hemispherical shape in the cupels, as quicksilver does in a cup of glass, while the fused oxyde spreads over, and penetrates their substance like water. A cupel may be regarded, in some measure, as a filter permeable only to certain liquids.

If we put into a cupel, therefore, two metals, of which the one is unalterable in the air, the other susceptible of oxydizement, and of producing a very fusible oxyde, it is obvious that, by exposing both to a proper degree of heat, we shall succeed in separating them. We should also succeed, though the oxyde were infusible, by placing it in contact with another one, which may render it fusible. In both cases, however, the metal from which we wish to part the oxydes must not be volatile; it should also melt, and form a button at the heat of cupellation; for otherwise it would continue disseminated, attached to the portion of oxyde spread over the cupel, and incapable of being collected.



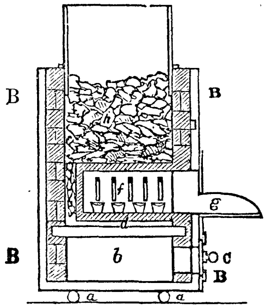
68

The furnace and implements used for assaying in the Royal Mint and the Goldsmiths' Hall, in the city of London, are the following:—

A A A A, *fig.* 68, is a front elevation of an assay furnace; *a a*, a view of one of the two iron rollers on which the furnace rests, and by means of which it is moved forward or backward; *b*, the ash-pit; *c c* are the ash-pit dampers, which are moved in a horizontal direction towards each other for regulating the draught of the furnace; *d*, the door, or opening, by which the cupels and assays are introduced into the muffle; *e*, a moveable funnel or chimney by which the draught of the furnace is increased.

B B B B, *fig.* 69, is a perpendicular section of *fig.* 68; *a a*, end view of the rollers; *b* the ash-pit; *c* one of the ash-pit dampers; *d* the grate, over which is the plate upon which the muffle rests, and which is covered with loam nearly one inch thick; *f* the muffle in section representing the situation of the cupels; *g* the mouth-plate, and upon it are laid pieces of charcoal, which during the process are ignited, and heat the air that is allowed to pass over the cupels, as will be more fully explained in the sequel; *h* the interior of the furnace, exhibiting the fuel.

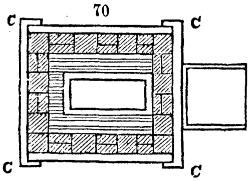
69



The total height of the furnace is 2 feet $6\frac{1}{2}$ inches; from the bottom to the grate, 6 inches; the grate, muffle, plate, and bed of loam, with which it is covered, 3 inches; from the upper surface of the grate to the commencement of the funnel *e*, *fig.* 68, $21\frac{1}{2}$ inches; the funnel *e*, 6 inches. The square of the furnace which receives the muffle and fuel is $11\frac{3}{4}$ inches by 15 inches. The external sides of the furnace are made of plates of wrought iron, and are lined with a 2-inch fire-brick.

C C C C, *fig.* 70, is a horizontal section of the furnace over the grates showing the width of the mouth-piece, or plate of wrought iron, which is 6 inches, and the opening which receives the muffle-plate.

70



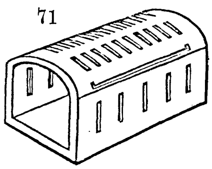
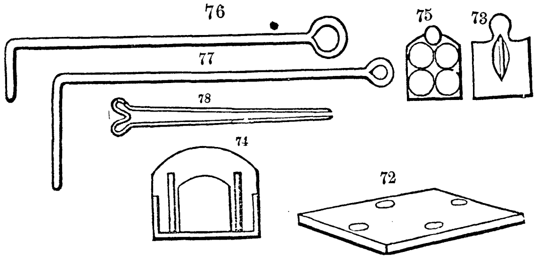


Fig. 71, represents the muffle or pot, which is 12 inches long, 6 inches broad inside; in the clear $6\frac{3}{4}$: in height $4\frac{1}{2}$ inside measure, and nearly $5\frac{1}{2}$ in the clear.

Fig. 72, the muffle-plate, which is of the same size as the bottom of the muffle.

Fig. 73, is a representation of the sliding-door of the mouth-plate, as shown at *d*, in *fig.* 68.



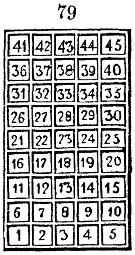


Fig. 74, a front view of the mouth-plate or piece, *d*, *fig.* 58.

Fig. 75, a representation of the mode of making, or shutting up with pieces of charcoal, the mouth of the furnace.

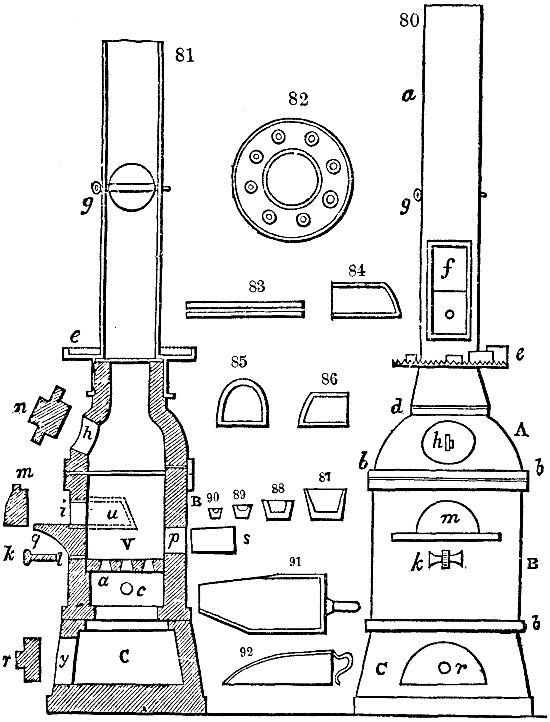
Fig. 76, the teaser for cleaning the grate.

Fig. 77, a larger teaser, which is introduced at the top of the furnace, for keeping a complete supply of charcoal around the muffle.

Fig. 78, the tongs used for charging the assays into the cups.

Fig. 79, represents a board of wood used as a register, and is divided into 45 equal compartments, upon which the assays are placed previously to their being introduced into the furnace. When the operation is performed, the cupels are placed in the furnace in situations corresponding to these assays on the board. By these means all confusion is avoided, and without this regularity it would be impossible to preserve the accuracy which the delicate operations of the assayer require.

I shall now proceed to a description of a small assay furnace, invented by Messrs. Anfrye and d'Arcet, of Paris. They term it, *Le Petit Fourneau à Coupelle.* *Fig.* 80 represents this furnace, and it is composed of a chimney or pipe of wrought iron *a*, and of the furnace B. It is $17\frac{1}{2}$ inches high, and $7\frac{1}{4}$ inches wide. The furnace is formed of three pieces; of a dome A; the body of the furnace B; and the ash-pit C, which is used as the base of the furnace, *figs.* 80 and 81. The principal piece, or body of the furnace, B, has the form of a hollow tower, or of a hollow cylinder, flattened equally at the two opposite sides parallel to the axis, in such a manner that the horizontal section is elliptical. The foot which supports it is a hollow truncated cone flattened in like manner upon the two opposite sides, and having consequently for its basis two ellipses of different diameters; the smallest ought to be equal to that of the furnace, so that the bottom of the latter may exactly fit it. The dome, which forms an arch above the furnace, has also its base elliptical, while that of the superior orifice by which the smoke goes out preserves the cylindrical form. The tube of wrought iron is 18 inches long and 2½ inches diameter, having one of its ends a little enlarged, and slightly conical, that it may be exactly fitted or jointed upon the upper part of the furnace dome *d*, *fig.* 80. At the union of the conical and cylindrical parts of the tube, there is placed a small gallery of iron, *e*, *fig.* 80, 81. See also a plan of it, *fig.* 82. This gallery is both ingenious and useful. Upon it are placed the cupels, which are thus annealed during the ordinary work of the furnace, that they may be introduced into the muffle, when it is brought into its proper degree of heat. A little above this gallery is a door *f*, by which, if thought proper, the charcoal could be introduced into the furnace; above that there is placed at g a throttle valve, which is used for regulating the draught of the furnace at pleasure. Messrs. Anfrye and d'Arcet say, that, to give the furnace the necessary degree of heat so as to work the assays of gold, the tube must be about 18 inches above the gallery, for annealing or heating the cupels. The circular opening *h*, in the dome, *fig.* 80, and as seen in the section, *fig.* 81, is used to introduce the charcoal into the furnace: it is also used to inspect the interior of the furnace, and to arrange the charcoal round the muffle. This opening is kept shut during the working of the furnace, with the mouthpiece, of which the face is seen at *n*, *fig.* 81.



The section of the furnace, *fig.* 81, presents several openings, the principal of which is that of the muffle; it is placed at *i*; it is shut with the semicircular door *m*, *fig.* 80, and seen in the section *m*, *fig.* 81. In front of this opening, is the table or shelf, upon which the door of the muffle is made to advance or recede; the letter *q*, *fig.* 81, shows the face, side, and cross section of the shelf, which makes part of the furnace. Immediately under the shelf, is a horizontal slit, *l*, which is pierced at the level of the upper part of the grate, and used for the introduction of a slender rod of iron, that the grate may be easily kept clean. This opening is shut at pleasure, by the wedge represented at *k*, *figs.* 80, and 81.

Upon the back of the furnace is a horizontal slit *p*, *fig.* 81, which supports the firebrick, *s*, and upon which the end of the muffle, if necessary, may rest; *u*, *fig.* 81, is the opening in the furnace where the muffle is placed.

The plan of the grate of the furnace is an ellipse: *fig.* 83, is a horizontal view of it. The dimensions of that ellipsis determine the general form of the furnace, and thickness of the grate. To give strength and solidity to the grate, it is encircled by a bar or hoop of iron. There is a groove in which the hoop of iron is fixed. The holes of the grate are truncated cones, having the greater base below, that the ashes may more easily fall into the ash-pit. The letter *v, fig.* 81, shows the form of these holes. The grate is supported by a small bank or shelf, making part of the furnace, as seen at *a, fig.* 81.

The ash-pit, c, has an opening *y* in front, *fig.* 81; and is shut when necessary by the mouth-piece, *r, figs.* 80 and 81.

To give strength and solidity to the furnace, it is bound with hoops of iron, at *b, b, b, b, fig.* 80.

Figs. 84, 85, 86, are views of the muffle.

Fig. 87, is a view of a crucible for annealing gold.

Figs. 88, 89, 90, are cupels of various sizes, to be used in the furnace. They are the same as those used by assayers in their ordinary furnaces.

Figs. 91 and 92 are views of the hand-shovels, used for filling the furnace with charcoal; they should be made of such size and form as to fit the opening *h*, in *figs.* 80 and 81.

The smaller pincers or tongs, by which the assays are charged into the cupels, and by which the latter are withdrawn from the furnace, as well as the teaser for cleaning the grate of the furnace, are similar to those used in the British Mint.

In the furnace of the Mint above described, the number of assays that can be made at one time is 45. The same number of cupels are put into the muffle. The furnace is then filled with charcoal to the top, and upon this are laid a few pieces already ignited. In the course of three hours, a little more or less, according to circumstances, the whole is ignited; during which period, the muffle, which is made of fire-clay, is gradually heated to redness, and is prevented from cracking; which a less regular or more sudden increase of temperature would not fail to do: the cupels, also, become properly annealed. All moisture being dispelled, they are in a fit state to receive the piece of silver or gold to be assayed.

The greater care that is exercised in this operation, the less liable is the assayer to accidents from the breaking of the muffle; which is both expensive and troublesome to fit properly into the furnace.

The cupels used in the assay process, are made of the ashes of burnt bones (phosphate of lime). In the Royal Mint, the cores of ox-horn are selected for this purpose; and the aashes produced are about four times the expense of the bone-ash, used in the process of cupellation upon a large scale. So much depends upon the accuracy of an assay of gold or silver, where a mass of 15lbs. troy in the first, and 60lbs troy in the second instance is determined by the analysis of a portion not exceeding 20 troy grains, that every precaution which the longest experience has suggested, is used to obtain an accurate result. Hence the attention paid to the selection of the most proper materials for making the cupels.

The cupels are formed in a circular mould made of cast steel, very nicely turned, by which means they are easily freed from the mould when struck. The bone-ash is used moistened with a quantity of water, sufficient to make the particles adhere firmly together. The circular mould is filled, and pressed level with its surface; after which, a pestle or rammer, having its end nicely turned, of a globular or convex shape, and of a size equal to the degree of concavity wished to be made in the cupel for the reception of the assay, is placed upon the ashes in the mould, and struck with a hammer until the cupel is properly formed. These cupels are allowed to dry in the air for some time before they are used. If the weather is fine, a fortnight will be sufficient.

An assay may prove defective for several reasons. Sometimes the button or bead sends forth crystalline vegetations on its surface with such force, as to make one suppose a portion of the silver may be thrown out of the cupel. When the surface of the bead is dull and flat, the assay is considered to have been too hot, and it indicates a loss of silver in fumes. When the tint of the bead is not uniform, when its inferior surface is bubbly, when yellow scales of oxyde of lead remain on the bottom of the cupel, and the bead adheres strongly to it, by these signs it is judged that the assay has been too cold, and that the silver retains some lead.

Lastly, the assay is thought to be good if the bead is of a round form, if its upper surface is brilliant, if its lower surface is granular and of a dead white, and if it separates readily from the cupel.

After the lead is put into the cupel, it gets immediately covered with a coat of oxyde, which resists the admission of the silver to be assayed into the melted metal; so that the alloy cannot form. When a bit of silver is laid on a lead bath in this predicament, we see it swim about for a long time without dissolving. In order to avoid this result, the silver is wrapped up in a bit of paper; and the carbureted hydrogen generated by its combustion reduces the film of the lead oxyde, gives the bath immediately a bright metallic lustre, and enables the two metals readily to combine.

As the heat rises, the oxyde of lead flows round about over the surface, till it is absorbed by the cupel. When the lead is wasted to a certain degree, a very thin film of it only remains on the silver, which causes the iridiscent appearance, like the colors of soap-bubbles; a phenomenon, called by the old chemists, fulguration.

When the cupel cools in the progress of the assay, the oxygenation of the lead ceases and, instead of a very liquid vitreous oxyde, an imperfectly melted oxyde is formed, which the cupel cannot absorb. To correct a cold assay, the temperature of the furnace ought to be raised, and pieces of paper ought to be put into the cupel, till the oxyde of lead which adheres to it be reduced. On keeping up the heat, the assay will resume its ordinary train.

Pure silver almost always vegetates. Some traces of copper destroy this property, which is obviously due to the oxygen which the silver can absorb while it is in fusion, and which is disengaged the moment it solidifies. An excess of lead, by removing all the copper at an early stage, tends to cause the vegetation.

The brightening is caused by the heat evolved, when the button passes from the liquid to the solid state. Many other substances present the same phenomenon.

In the above operation it is necessary to employ lead which is very pure, or at least free from silver. That kind is called *poor lead.*

It has been observed at all times, that the oxyde of lead carries off with it, into the cupel, a little silver in the state of an oxyde. This effect becomes less, or even disappears, when there is some copper remaining; and the more copper, the less chance there is of any silver being lost. The loss of silver increases, on the other hand, with the dose of lead. Hence the reason why it is so important to proportion the lead with a precision which, at first sight, would appear to be superfluous. Hence, also, the reason of the attempts which have, of late years, been made to change the whole system of silver assays, and to have recourse to a method exempt from the above causes of error.

M. d'Arcet, charged by the Commission of the Mint in Paris, to examine into the justice of the reclamations made by the French silversmiths against the public assays, ascertained that they were well founded; and that the results of cupellation gave for the alloys betwen 897 and 903 thousandths (the limits of their standard coin) an inferior standard, by from 4 to 5 thousandth parts, from the standard or title which should result from the absolute or actual alloy.

The mode of assay shows, in fact, that an ingot, experimentally composed of 900 thousandths of fine silver, and 100 thousandths of copper, appears, by cupellation, to be only, at the utmost, 896 or 897 thousandths; whereas fine silver, of 1000 thousandths, comes out nearly of its real standard. Consequently a director of the Mint, who should compound his alloy with fine silver, would be obliged to employ 903 or 904 thousandths, in order that, by the assay in the laboratory of the Mint, it should appear to have the standard of 900 thousandths. These 3 or 4 thousandths would be lost to him, since they would be disguised by the mode of assay, the definitive criterion of the quantity of silver, of which the government keeps count from the coiner of the money.

From the experiments subsequently made by M. d'Arcet, it appears that silver assays always suffer a loss of the precious metal, which varies, however, with the standard of the alloy. It is 1 thousandth for fine silver,

4·3 thousandths for silver of 900 thousandths,
4·9 — for — of 800 —
4·2 — for — of 500 —

and diminishes thereafter, progressively, till the alloy contains only 100 thousandths of silver, at which point the loss is only 0·4.

Assays requested by the Commission of the Paris Mint, from the assayers of the principal Royal Mints in Europe, to which the same alloys, synthetically compounded, were sent, afforded the results inscribed in the following table.

Names of the Assayers.	Cities where they reside.	Standards found for the Mathematical Alloys		
		950 mill.	900 mill.	800 mill.
F. de Castenhole, Mint Assayer	Vienna	946·20	898 40	795·10
A. R. Vervaëz, ditto -	Madrid	944·40	893·70	789·20
D. M. Cabrera, Assayer in Spain - - - - -	Ditto	944·40	893·70	788·60
Assayer - - - - -	Amsterdam	947·00	895·00	795·00
Mr. Bingley, Assay Master -	London	946·25	896·25	794·25
Mr. Johnson, Assayer - -	Ditto	933·33	883·50	783·33
Inspector of the Mint - -	Utrecht	945·00	896·50	799·00
Assayer of the Mint - -	Naples	945·00	891·00	787·00
Assayer of Trade - - -	Ditto	945·00	891·00	787·00
Assayer of the Mint . - -	Hamburgh	946·$\frac{13}{72}$	897·$\frac{41}{72}$	798·$\frac{44}{72}$
Ditto - - - -	Altona	942·$\frac{1}{4}$	894·00	790

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These results, as well as those in still greater numbers, obtained from the ablest Parisian assayers, upon identical alloys of silver and copper, prove that the mode of assay applied to them brings out the standard too low; and further, that the quantity of silver masked or disguised, is not uniform for these different eminent assay masters. An alloy, for example, at the standard of 900 thousandths is judged at

		M.
the Mint of Paris to have a standard of		895·6
At that of Vienna	—	898·4
— Madrid	—	893·7
— Naples	—	891·0

The fact thus so clearly made out of a loss in the standard of silver bullion and coin, merits the most serious attention; and it will appear astonishing, perhaps, that a thing recurring every day, should have remained for so long a time in the dark. In reality, however, the fact is not new; as the very numerous and well-made experiments of Tillet, from 1760 to 1763, which are related in the memoirs of the Academy of Sciences, show, in the silver assays, a loss still greater than that which was experienced lately in the laboratory of the Commission of the French Mint. But he thought that, as the error was common to the nations in general, it was not worth while or prudent to introduce any innovation.

A mode of assaying, to give, with certainty, the standard of silver bullion, should be entirely independent of the variable circumstances of temperature, and the unknown proportions of copper, so difficult to regulate by the mere judgment of the senses. The process by the humid way, recommended by me to the Royal Mint in 1829, and exhibited as to its principles before the Right Honorable John Herries, then Master, in 1830, has all the precision and certainty we could wish. It is founded on the well-known property which silver has, when dissolved in nitric acid, to be precipitated in a chloride of silver quite insoluble, by a solution of sea salt, or by muriatic acid; but, instead of determining the weight of the chloride of silver, which would be somewhat uncertain and rather tedious, on account of the difficulty of drying it, we take the quantity of the solution of sea salt which has been necessary for the precipitation of the silver. To put the process in execution, a liquor is prepared, composed of water and sea salt in such proportions that 1000 measures of this liquor may precipitate, completely, 12 grains of silver, perfectly pure, or of the standard 1000, previously dissolved in nitric acid. The liquor thus prepared, gives, immediately, the true standard of any alloy whatever, of silver and copper, by the weight of it which may be necessary to precipitate 12 grains of this alloy If, for example, 905 measures have been required to precipitate the 12 grains of alloy, its standard would be 905 thousandths.

The process by the humid way is, so to speak, independent of the operator. The manipulations are so easy; and the term of the operation is very distinctly announced by the absence of any sensible nebulosities on the affusion of sea salt into the silver solution, while there remains in it ½ thousandth of metal. The process is not tedious, and in experienced hands it may rival the cupel in rapidity; it has the advantage over the cupel of being more within the reach of ordinary operators, and of not requiring a long apprenticeship. It is particularly useful to such assayers as have only a few assays to make daily, as it will cost them very little time and expense.

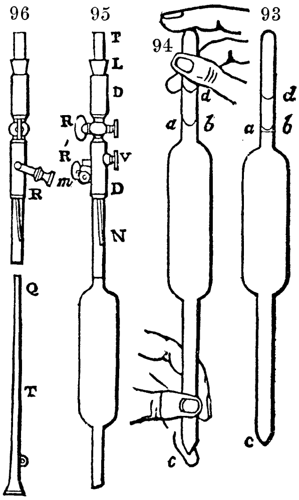
By agitating briskly during two minutes, or thereby, the liquid rendered milky by the precipitation of the chloride of silver, it may be sufficiently clarified to enable us to appreciate, after a few moments of repose, the disturbance that can be produced in it by the addition of 1000 of a grain of silver. Filtration is more efficacious than agitation, especially when it is employed afterwards; it may be sometimes used; but agitation, which is much more prompt, is generally sufficient. The presence of lead and copper, or any other metal, except mercury, has no perceptible influence on the quantity of sea salt necessary to precipitate the silver; that is to say, the same quantity of silver, pure or alloyed, requires for its precipitation a constant quantity of the solution of sea salt.

Supposing that we operate upon a gramme of pure silver, the solution of sea salt ought to be such that 100 centimetres cube may precipitate exactly the whole silver. The standard of an alloy is given by the number of thousandths of solution of sea salt necessary to precipitate the silver contained in a gramme of the alloy.

When any mercury is accidentally present, which is, however, a rare occurrence, it is made obvious by the precipitated chloride remaining white when exposed to daylight, whereas when there is no mercury present, it becomes speedily first gray and then purple. Silver so contaminated must be strongly ignited in fusion before being assayed, and its loss of weight noted. In this case, a cupel assay must be had recourse to.

Preparation of the Normal Solution of Sea Salt, when it is measured by Weight.—Supposing the sea salt pure as well as the water, we have only to take these two bodies in the proportion of 0·5427 k. of salt to 99·4573 k. of water, to have 100 k. of solution, of which 100 grammes will precipitate exactly one gramme of silver. But instead of pure salt, which is to be procured with difficulty, and which besides may be altered readily by absorbing the humidity of the air, a concentrated solution of the sea salt of commerce is to be preferred, of which a large quantity may be prepared at a time, to be kept in reserve for use, as it is wanted. *Instruction de Gay Lussac.*

Preparation of the Normal Solution of Sea Salt, when measured by Volume.—The measure by weight has the advantage of being independent of temperature, of having the same degree of precision as the balance, and of standing in need of no correction. The measure by volume has not all these advantages; but, by giving it sufficient precision, it is more rapid, and is quite sufficient for the numerous daily assays of the mint. This normal solution is so made, that a volume equal to that of 100 grammes of water, or 100 centimetres cube, at a determinate temperature, may precipitate exactly one gramme of silver. The solution may be kept at a constant temperature, and in this case the assay stands in want of no correction; or if its temperature be variable, the assay must be corrected according to its influence. These two circumstances make no change in the principle of the process, but they are sufficiently important to occasion some modifications in the apparatus. Experience has decided the preference in favor of applying a correction to a variable temperature.



We readily obtain a volume of 100 cubic centimetres by means of a *pipette, fig.* 93, so gauged that when filled with water up to the mark *a*, *b*, and well dried at its point, it will run out, at a continuous efflux, 100 grammes of water at the temperature of 15 C. (59 Fah.). We say purposely at one efflux, because after the cessation of the jet, the pipette may still furnish two or three drops of liquid, which must not be counted or reckoned upon. The weight of the volume of the normal solution, taken in this manner with suitable precautions, will be uniform from one extreme to another, upon two centimetres and a half, at most, or to a quarter of a thousandth, and the difference from the mean will be obviously twice less, or one half. Let us indicate the most simple manner of taking a measure of the normal solution of sea salt.

After having immersed the beak *c* of the pipette in the solution, we apply suction by the mouth, to the upper orifice, and thereby raise the liquid to *d*, above the circular line *a b*. We next apply neatly the forefinger of one hand to this orifice, remove the pipette from the liquid, and seize it as represented in *fig.* 94. The mark *a b* being placed at the level of the eye, we make the surface of the solution become exactly a tangent to the plane *a b*. At the instant it becomes a tangent, we leave the beak *c* of the pipette open, by taking away the finger that had been applied to it, and without changing anything else in the position of the hands, we empty it into the bottle which should receive the solution, taking care to remove it whenever the efflux has run out.

If, after filling the pipette by suction, any one should find a difficulty in applying the forefinger fast enough to the upper orifice, without letting the liquid run down below the mark *a b*, he should remove the pipette from the solution with its top still closed with his tongue, then apply the middle finger of one of his hands to the lower orifice; after which he may withdraw his tongue, and apply the forefinger of the other hand to the orifice previously wiped. This mode of obtaining a measure of normal solution of sea salt is very simple, and requires no complex apparatus: but we shall indicate another manipulation still easier, and also more exact.

In this new process the pipette is filled from the top like a bottle, instead of being filled by suction, and it is moreover fixed. *Fig.* 95 represents the apparatus. D and D′ are two sockets separated by a stop-cock R. The upper one, tapped interiorly, receives, by means of a cork stopper L, the tube T, which admits the solution of sea salt. The lower socket is cemented on to the *pipette;* it bears a small air-cock R′, and a screw plug V, which regulates a minute opening intended to let the air enter very slowly into the pipette. Below the stop-cock R′, a silver tube N, of narrow diameter, soldered to the socket, leads the solution into the *pipette*, by allowing the air, which it displaces, to escape by the stop-cock R′. The screw plug, with the milled head V′, replaces the ordinary screw by which the key of the stop-cock may be made to press, with more or less force, upon its conical seat.

Fig. 96 represents, in a side view, the apparatus just described. We here remark an air-cock R, and an opening *m*. At the extremity Q of the same figure, the conical pipe T enters, with friction. It is by this pipe that the air is sucked into the pipette when it is to be filled from its beak.

The *pipette* is supported by two horizontal arms H K (*fig.* 97) moveable about a common axis A A, and capable of being drawn out or shortened by the aid of two longitudinal slits. They are fixed steadily by two screw nuts *e é*, and their distance may be varied by means of round bits of wood or cork interposed, or even by opposite screw nuts *o ó*. The upper arm H is pierced with a hole, in which is fixed, by the pressure of a wooden screw *v*, the socket of the *pipette*. The corresponding hole of the lower arm is larger; and the beak of the *pipette* is supported in it by a cork stopper L. The apparatus is fixed by its tail-piece P, by means of a screw, to the corner of a wall, or any other prop.

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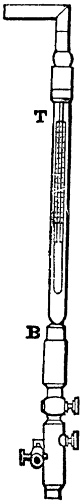

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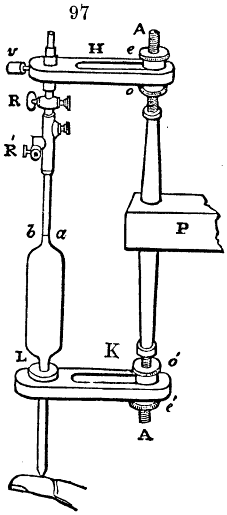
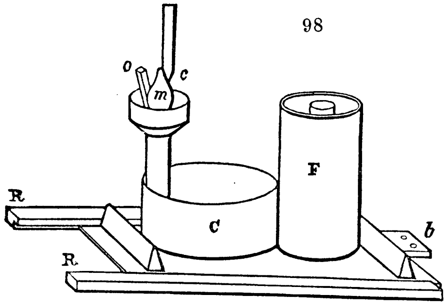


The manner of filling the pipette is very simple. We begin by applying the fore-finger of the left hand to the lower aperture *c;* we then open the two stop-cocks R and R'. Whenever the liquor approaches the neck of the *pipette*, we must temper its influx, and when it has arrived at some millimetres above the mark *a b*, we close the two stop-cocks, and remove our fore-finger. We have now nothing more to do than to regulate the *pipette;* for which purpose the liquid must touch the line *a b*, and must simply adhere externally to the beak of the *pipette.*

This last circumstance is easily adjusted. After taking away the finger which closed the aperture *c* of the *pipette*, we apply to this orifice a moist sponge *m*, *fig.* 98, wrapped up in a linen rag, to absorb the superfluous liquor as it drops out. This sponge is called the handkerchief (*mouchoir*), by M. Gay Lussac. The *pipette* is said to be wiped when there is no liquor adhering to its point exteriorly.

98



For the convenience of operating, the handkerchief is fixed by friction in a tube of tin plate, terminated by a cup, open at bottom to let the droppings flow off into the cistern C, to which the tube is soldered. It may be easily removed for the purpose of washing it; and, if necessary, a little wedge of wood, *o*, can raise it toward the *pipette*.

To complete the adjustment of the *pipette*, the liquid must be made merely to descend to the mark *a*, *b*. With this view, and while the handkerchief is applied to the beak o the *pipette*, the air must be allowed to enter very slowly by unscrewing the plug V, *fig.* 95; and at the moment of the contact the handkerchief must be removed, and the bottle F, destined to receive the solution, must be placed below the orifice of the *pipette*, *fig.* 98. As the motion must be made rapidly, and without hesitation, the bottle is placed in a cylinder of tin-plate, of a diameter somewhat greater, and forming one body with the cistern and the handkerchief. The whole of this apparatus has for a basis a plate of tinned iron, moveable between two wooden rulers R R, one of which bears a groove, under which the edge of the plate slips. Its traverses are fixed by two abutments *b b*, placed so that when it is stopped by one of them, the beak of the *pipette* corresponds to the centre of the neck of the bottle, or is a tangent to the handkerchief. This arrangement, very convenient for wiping the *pipette* and emptying it, gives the apparatus sufficient solidity, and allows of its being taken away and replaced without deranging anything. It is obvious that it is of advantage, when once the entry of the air into the *pipette* has been regulated by the screw V, to leave it constantly open, because the motion from the handkerchief to the bottle is performed with sufficient rapidity to prevent a drop of the solution from collecting and falling down.

Temperature of the Solution.—After having described the manner of measuring by volume the normal solution of the sea salt, we shall indicate the most convenient means of taking the temperature. The thermometer is placed in a tube of glass T, *fig.* 89, which the solution traverses to arrive at the *pipette*. It is suspended in it by a piece of cork, grooved on the four sides to afford passage to the liquid. The scale is engraved upon the tube itself, and is repeated at the opposite side, to fix the eye by the coincidence of this double division at the level of the thermometric column. The tube is joined below to another narrower one, through which it is attached by means of a cork stopper B, in the socket of the stop-cock of the *pipette*. At its upper part it is cemented into a brass socket, screw-tapped in the inside, which is connected in its turn by a cock, with the extremity, also tapped, of the tube above T, belonging to the reservoir of the normal solution. The corks employed here as connecting links between the parts of the apparatus, give them a certain flexibility, and allow of their being dismounted and remounted in a very short time; but it is indispensable to make them be traversed by a hollow tube of glass or metal, which will hinder them from being crushed by the pressure they are exposed to. If the precaution be taken to grease them with a little suet, and to fill their pores, they will suffer no leakage.

Preservation of the Normal Solution of Sea Salt in metallic Vessels.—M. Gay Lussac uses for this purpose a cylindrical vessel or drum of copper, of a capacity of about 110 litres, having its inside covered with a rosin and wax cement.

Preparation of the Normal Solution of Sea Salt, measuring it by Volume.—If the drum contains 110 litres, we should put only 105 into it, in order that sufficient space may be left for agitating the liquor without throwing it out. According to the principle that 100 centimetres cube, or $\frac{1}{10}$ of a litre of the solution should contain enough of sea salt to precipitate a gramme of pure silver; and, admitting, moreover, 13·516 for the prime equivalent of silver, and 7·335 for that of sea salt, we shall find the quantity of pure salt that should be dissolved in the 105 litres of water, and which corresponds to 105 × 10 = 1050 grammes of silver, to be by the following proportion:—

13·516 : 7·335 :: 1050 gramm. : x=569·83 gr.

And as the solution of the sea salt of commerce, formerly mentioned, contains approximately 250 grammes per kilogramme, we must take 2279·3 grammes of this solution to have 569·83 gram. of salt. The mixture being perfectly made, the tubes and the *pipette* must be several times washed by running the solution through them, and putting it into the drum. The standard of the solution must be determined after it has been well agitated, supposing the temperature to remain uniform.

To arrive more conveniently at this result, we begin by preparing two *decimes* solutions; one of silver, and another of sea salt.

The decime solution of silver is obtained by dissolving 1 gramme of silver in nitric acid, and diluting the solution with water till its volume becomes a litre.

The decime solution of sea salt may be obtained by dissolving 0·543 grammes of pure sea salt in water, so that the solution shall occupy a litre; but we shall prepare it even with the normal solution which we wish to test, by mixing a measure of it with 9 measures of water; it being understood that this solution is not rigorously equivalent to that of silver, and that it will become so, only when the normal solution employed for its preparation shall be finally of the true standard. Lastly, we prepare beforehand several stoppered vials, in each of which we dissolve 1 gramme of silver in 8 or 10 grammes of nitric acid. For brevity's sake we shall call these tests.

Now to investigate the standard of the normal solution, we must transfer a *pipette* of it into one of these test vials; and we must agitate the liquors briskly to clarify them. After some instants of repose, we must pour in 2 thousandths of the *decime* solution of sea salt, which, we suppose, will produce a precipitate. The normal liquor is consequently too feeble; and we should expect this, since the sea salt employed was not perfectly pure. We agitate and add 2 fresh thousandths, which will also produce a precipitate. We continue thus by successive additions of 2 thousandths, till the last produces no precipitation. Suppose that we have added 16 thousandths: the last two should not be reckoned, as they produced no precipitate; the preceding two were necessary, but only in part; that is to say, the useful thousandths added are above 12 and below 14, or otherwise they are on an average equal to 13.

Thus, in the condition of the normal solution, we require 1013 parts of it to precipitate one gramme of silver, while we should require only 1000. We shall find the quantity of concentrated solution of sea salt that we should add, by noting that the quantity of solution of sea salt, at first employed, viz. 2279·3 grammes, produced a standard of only 987 thousandths=1000—13; and by using the following proportion:

987 : 2279·3 :: 13 : x=30·02 grammes.

This quantity of the strong solution of salt, mixed with the normal solution in the drum, will correct its standard, and we shall now see by how much.

After having washed the tubes and the *pipette* with the new solution, we must repeat the experiment upon a fresh gramme of silver. We shall find, for example, in proceeding only by a thousandth at a time, that the first causes a precipitate, but not the second. The standard of the solution is still too weak, and is comprised between 1000 and 1001; that is to say, it may be equal to 1000½, but we must make a closer approximation.

We pour into the test bottle 2 thousandths of the *decime* solution of silver which will destroy, perceptibly, two thousandths of sea salt, and the operation will have retrograded by two thousandths; that is to say, it will be brought back to the point at which it was first of all. If, after having cleared up the liquor, we add half a thousandth of the decime solution, there will necessarily be a precipitate, as we knew beforehand, but a second will cause no turbidity. The standard of the normal liquor will be consequently comprehended between 1000 and 1000½, or equal to 1000¼.

We should rest content with this standard, but if we wish to correct it, we may remark that the two quantities of solution of salt added, viz. 2279·3 gr. + 30·02 gr.= 2309·32 gr. have produced only 999·75 thousandths, and that we must add a new quantity of it corresponding to ¼ of a thousandth. We make, therefore, the proportion

$$999{\cdot}75 : 2309{\cdot}32 :: 0{\cdot}25 : x.$$

But since the first term differs very little from 1000, we may content ourselves to have x by taking the $\frac{0\cdot25}{1000}$ of 2309·32, and we shall find 0·577 gr. for the quantity of solution of sea salt to be added to the normal solution.

It is not convenient to take exactly so small a quantity of solution of sea salt by the balance, but we shall succeed easily by the following process. We weigh 50 grammes of this solution, and we dilute it with water; so that it occupies exactly half a litre, or 500 centimetres cube. A *pipette* of this solution, one centimetre cube in volume, will give a decigramme of the primitive solution, and as such a small *pipette* is divided into twenty drops, each drop, for example, will represent 5 milligrammes of the solution. We should arrive at quantities smaller still by diluting the solution with a proper quantity of water; but greater precision would be entirely needless.

The testing of the normal liquor just described, is, in reality, less tedious than might be supposed. It deserves also to be remarked, that liquor has been prepared for more than 1000 assays; and that, in preparing a fresh quantity, we shall obtain directly its true standard, or nearly so, if we bear in mind the quantities of water and solution of salt which had been employed.

Correction of the Standard of the Normal Solution of Sea Salt, when the Temperature changes.—We have supposed, in determining the standard of the normal solution of sea salt, that the temperature remained uniform. The assays made in such circumstances, have no need of correction; but if the temperature should change, the same measure of the solution will not contain the same quantity of sea salt. Supposing that we have tested the solution of the salt at the temperature of 15° C.; if, at the time of making the experiment, the temperature is 18° C., for example, the solution will be too weak on account of its expansion, and the *pipette* will contain less of it by weight; if, on the contrary, the temperature has fallen to 12°, the solution will be thereby concentrated and will prove too strong. It is therefore proper to determine the correction necessary to be made, for any variation of temperature.

To ascertain this point, the temperature of the solution of sea salt was made successively to be 0°, 5°, 10°, 15°, 20°, 25°, and 30° C.; and three *pipettes* of the solution were weighed exactly at each of these temperatures. The third of these weighings gave the mean weight of a *pipette*. The corresponding weights of a *pipette* of the solution, were afterwards graphically interpolated from degree to degree. These weights form the second column of the following table, entitled, *Table of Correction for the Variations in the Temperature of the Normal Solution of the Sea Salt.* They enable us to correct any temperature between 0 and 30 degrees centigrade (32° and 86° Fahr.) when the solution of sea salt has been prepared in the same limits.

Let us suppose, for example, that the solution has been made standard at 15°, and that, at the time of using it, the temperature has become 18°. We see by the second column of the table, that the weight of a measure of the solution is 100·099 gr. at 15°, and 100·065 at 18°; the difference 0·034 gr., is the quantity of solution less which has been really taken; and of course we must add it to the normal measure, in order to make it equal to one thousand *milliemes.* If the temperature of the solution had fallen to 10 degrees, the difference of the weight of a measure from 10 to 15 degrees would be 0·019 gr., which we must on the contrary deduct from the measure, since it had been taken too large. These differences of weight of a measure of solution at 15°, from that of a measure at any other temperature, form the column 15° of the table, where they are expressed in thousandths; they are inscribed on the same horizontal lines as the temperatures to which each of them relates, with the sign + *plus*, when they must be added, and with the sign — *minus*, when they must be subtracted. The columns 5°, 10°, 20°, 25°, 35°, have been calculated in the same manner for the cases in which the normal solution may have been graduated to each of these temperatures. Thus, to calculate the column 10, the number 100·118 has been taken of the column of weights for a term of departure, and its difference from all the numbers of the same column has been sought.

Table of Correction for the Variations in the Temperature of the Normal Solution of the Sea Salt.

Temperature.	Weight.	5°	10°	15°	20°	25°	30°
	gram.	mill.	mill.	mill.	mill.	mill.	mill.
4	100,109	0·0	— 0·1	+ 0·1	+ 0·7	+ 1·7	+ 2·7
5	100,113	0·0	— 0·1	+ 0·1	+ 0·7	+ 1·7	+ 2·8
6	100,115	0·0	0·0	+ 0·2	+ 0·8	+ 1·7	+ 2·8
7	110,118	+ 0·1	0·0	+ 0·2	0·8	+ 1·7	+ 2·8
8	100,120	+ 0·1	0·0	+ 0·2	+ 0·8	+ 1·8	+ 2·8
9	100,120	+ 0·1	0·0	+ 0·2	+ 0·8	+ 1·8	+ 2·8
10	100,118	+ 0·1	0·0	+ 0·2	+ 0·8	+ 1·7	+ 2·8
11	100,116	0·0	0·0	+ 0·2	+ 0·8	+ 1·7	+ 2·8
12	100,114	0·0	0·0	+ 0·2	+ 0·8	+ 1·7	+ 2·8
13	100,110	0·0	— 0·1	+ 0·1	+ 0·7	+ 1·7	+ 2·7
14	100,106	— 0·1	— 0·1	+ 0·1	+ 0·7	+ 1·6	+ 2·7
15	100,099	— 0·1	— 0·2	— 0·0	+ 0·6	+ 1·6	+ 2·6
16	100,090	— 0·2	— 0·3	— 0·1	+ 0·5	+ 1·5	+ 2·5
17	100,078	— 0·4	— 0·4	— 0·2	+ 0·4	+ 1·3	+ 2·4
18	100,065	— 0·5	— 0·5	— 0·3	+ 0·3	+ 1·2	+ 2·3
19	100,053	— 0·6	— 0·7	— 0·5	+ 0·1	+ 1·1	+ 2·2
20	100,039	— 0·7	— 0·8	— 0·6	0·0	+ 1·0	+ 2·0
21	100,021	— 0·9	— 1·0	— 0·8	— 0·2	+ 0·8	+ 1·9
22	100,001	— 1·1	— 1·2	— 1·0	— 0·4	+ 0·6	+ 1·7
23	99,983	— 1·3	— 1·4	— 1·2	— 0·6	+ 0·4	+ 1·5
24	99,964	— 1·5	— 1·5	— 1·4	— 0·8	+ 0·2	+ 1·3
25	99,944	— 1·7	— 1·7	— 1·6	— 1·0	0·0	+ 1·1
26	99,924	— 1·9	— 1·9	— 1·8	— 1·2	— 0·2	+ 0·9
27	99,902	— 2·1	— 2·2	— 2·0	— 1·4	— 0·4	+ 0·7
28	99,879	— 2·3	— 2·4	— 2·2	— 1·6	— 0·7	+ 0·4
29	99,858	— 2·6	— 2·6	— 2·4	— 1·8	— 0·9	+ 0·2
30	99,836	— 2·8	— 2·8	— 2·6	— 2·0	— 1·1	0·0

Several expedients have been employed to facilitate and abridge the manipulations. In the first place, the vials for testing or assaying the specimens of silver should all be of the same height and of the same diameter. They should be numbered at their top, as well as on their stoppers, in the order 1, 2, 3, &c. They may be ranged successively in tens; the stoppers of the same series being placed on a support in their proper order. Each two vials should, in their turn, be placed in a japanned tin case (*fig.* 100), with ten compartments duly numbered. These compartments are cut out anteriorly to about half their height, to allow the bottoms of the bottles to be seen. When each vial has received its portion of alloy, through a wide-beaked funnel, there must be poured into it about 10 grammes of nitric acid, of specific gravity 1·28, with a *pipette*, containing that quantity; it is then exposed to the heat of a water bath, in order to facilitate the solution of the alloy. The water bath is an oblong vessel made of tin plate, intended to receive the vials. It has a moveable double bottom, pierced with small holes, for the purpose of preventing the vials being broken, as it insulates them from the bottom to which the heat is applied. The solution is rapid; and, since it emits nitrous vapors in abundance, it ought to be carried on under a chimney.

The agitator.—*Fig.* 101 gives a sufficiently exact idea of it, and may dispense with a lengthened description. It has ten cylindrical compartments, numbered from 1 to 10. The vials, after the solution of the alloy, are arranged in it in the order of their numbers. The agitator is then placed within reach of the *pipette*, intended to measure out the normal solution of sea salt, and a *pipette* full of this solution is put in each vial. Each is then closed with its glass stopper, previously dipped in pure water. They are fixed in the cells of the agitator by wooden wedges. The agitator is then suspended

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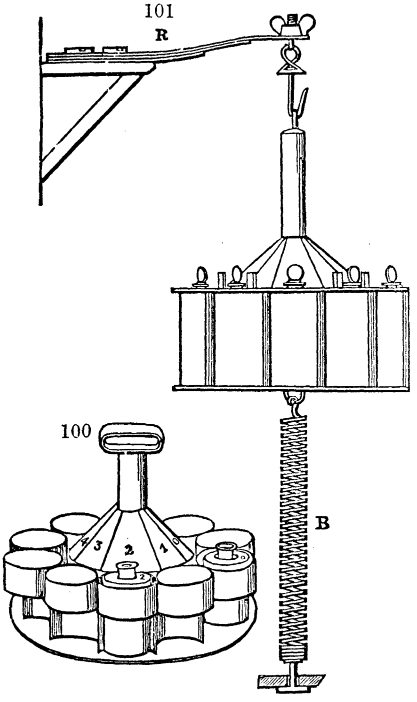
to a spring R, and, seizing it with the two hands, the operator gives an alternating rapid movement, which agitates the solution, and makes it, in less than a minute, as limpid as water. This movement is promoted by a spiral spring, B, fixed to the agitator and the ground, but this is seldom made use of, because it is convenient to be able to transport the agitator from one place to another. When the agitation is finished, the wedges are to be taken out, and the vials are placed in order upon a table furnished with round cells destined to receive them, and to screen them from too free a light.

101



100

When we place the vials upon this table, we must give them a brisk circular motion, to collect the chloride of silver scattered round their sides; we must lift out their stoppers, and suspend them in wire rings, or pincers. We next pour a thousandth of the decime solution into each vial; and before this operation is terminated, there is formed in the first vials, when there *should be* a precipitate, a nebulous stratum, very well marked, of about a centimetre in thickness.

At the back of the table there is a black board divided into compartments numbered from 1 to 10, upon each of which we mark, with chalk, the thousandths of the decime liquor put into the correspondent vial. The thousandths of sea salt, which indicate an augmentation of standard, are preceded by the sign +, and the thousandths of nitrate of silver by the sign —.

When the assays are finished, the liquor of each vial is to be poured into a large vessel, in which a slight excess of sea salt is kept; and when it is full, the supernatant clear liquid must be run off with a syphon.

The chloride of silver may be reduced without any perceptible loss. After having washed it well, we immerse pieces of iron or zinc into it, and add sulphuric acid in sufficient quantity to keep up a feeble disengagement of hydrogen gas. The mass must not be touched. In a few days the silver is completely reduced. This is easily recognised by the color and nature of the product; or by treating a small quantity of it with water of ammonia, we shall see whether there be any chloride unreduced; for it will be dissolved by the ammonia, and will afterwards appear upon saturating the ammonia with an acid. The chlorine remains associated with the iron or the zinc in a state of solution. The first washings of the reduced silver must be made with an acidulous water, to dissolve the oxyde of iron which may have been formed, and the other washings with common water. After decanting the water of the last washing, we dry the mass, and add a little powdered borax to it. It must be now fused. The silver being in a bulky powder, is to be put in successive portions into a crucible as it sinks down. The heat should be at first moderate; but towards the end of the operation it must be pretty strong to bring into complete fusion the silver and the scoriæ, and to effect their complete separation. In case it should be supposed that the whole of the silver had not been reduced by the iron or zinc, a little carbonate of potash should be added to the borax. The silver may also be reduced by exposing the chloride to a strong heat, in contact with chalk and charcoal.

The following remarks by M. Gay Lussac, the author of the above method, upon the effect of a little mercury in the humid assay, are important:—

It is well known that chloride of silver blackens the more readily as it is exposed to an intense light, and that even in the diffused light of a room, it becomes soon sensibly colored. If it contains four to five thousandths of mercury, it does not blacken; it remains of a dead white: with three thousandths of mercury, there is no marked discoloring in diffused light; with two thousandths it is slight; with one it is much more marked, but still it is much less intense than with pure chloride. With half a thousandth of mercury the difference of color is not remarkable, and is perceived only in a very moderate light.

But when the quantity of mercury is so small that it cannot be detected by the difference of color in the chloride of silver, it may be rendered quite evident by a very simple process of concentration. Dissolve one gramme of the silver supposed to contain $\frac{1}{4}$ of a thousandth of mercury, and let only $\frac{1}{4}$ of it be precipitated, by adding only $\frac{1}{4}$ of the common salt necessary to precipitate it entirely. In thus operating, the $\frac{1}{4}$ thousandth of mercury is concentrated in a quantity of chloride of silver four times smaller: it is as if the silver having been entirely precipitated, four times as much mercury equal to two thousandths, had been precipitated with it.

In taking two grammes of silver, and precipitating only $\frac{1}{4}$ by common salt, the precipitate would be, with respect to the chloride of silver, as if it amounted to four thousandths. By this process, which occupies only five minutes, because exact weighing is not necessary, $\frac{1}{10}$ of a thousandth of mercury may be detected in silver.

It is not useless to observe, that in making those experiments the most exact manner of introducing small quantities of mercury into a solution of silver, is to weigh a minute globule of mercury, and to dissolve it in nitric acid, diluting the solution so that it may contain as many cubic centimetres as the globule weighs of centigrammes. Each cubic centimetre, taken by means of a *pipette*, will contain one milligramme of mercury.

If the ingot of silver to be assayed is found to contain a greater quantity of mercury, one thousandth for example, the humid process ought either to be given up in this case, or to be compared with cupellation.

When the silver contains mercury, the solution from which the mixed chlorides are precipitated does not readily become clear.

Silver containing mercury, put into a small crucible and mixed with lamp-black, to prevent the volatilization of the silver, was heated for three quarters of an hour in a muffle, but the silver increased sensibly in weight. This process for separating the mercury, therefore, failed. It is to be observed, that mercury is the only metal which has thus the power of disturbing the analysis by the humid way.

Assaying of Gold.—In estimating or expressing the fineness of gold, the whole mass spoken of is supposed to weigh 24 carats of 12 grains each, either real, or merely proportional, like the assayer's weights; and the pure gold is called fine. Thus, if gold be said to be 23 carats fine, it is to be understood, that in a mass, weighing 24 carats, the quantity of pure gold amounts to 23 carats.

In such small work as cannot be assayed by scraping off a part and cupelling it, the assayers endeavor to ascertain its fineness or quality by the touch. This is a method of comparing the color and other properties, of a minute portion of the metal, with those of small bars, the composition of which is known. These bars are called touch needles, and they are rubbed upon a smooth piece of black basaltes or pottery, which, for this reason, is called the touchstone. Black flint slate will serve the same purpose. Sets of gold needles may consist of pure gold; of pure gold, 23½ carats with ½ carat of silver; 23 carats of gold with one carat of silver; 22½ carats of gold with 1½ carat of silver; and so on, till the silver amounts to four carats; after which the additions may proceed by whole carats. Other needles may be made in the same manner, with copper instead of silver; and other sets may have the addition, consisting either of equal parts of silver and copper, or of such proportions as the occasions of business require. The examination by the touch may be advantageously employed previous to quartation, to indicate the quantity of silver necessary to be added.

In foreign countries, where trinkets and small work are required to be submitted to the assay of the touch, a variety of needles is necessary; but they are not much used in England. They afford, however, a degree of information which is more considerable than might at first be expected. The attentive assayer compares not only the color of the stroke made upon the touchstone by the metal under examination, with that produced by his needle, but will likewise attend to the sensation of roughness, dryness, smoothness, or greasiness, which the texture of the rubbed metal excites, when abraded by the stone. When two strokes perfectly alike in color are made upon the stone, he may then wet them with aquafortis, which will affect them very differently, if they be not similar compositions; or the stone itself may be made red-hot by the fire, or by the blowpipe, if thin black pottery be used; in which case the phenomena of oxydation will differ according to the nature and quantity of the alloy. Six principal circumstances appear to affect the operation of parting; namely, the quantity of acid used in parting, or in the first boiling; the concentration of this acid; the time employed in its application; the quantity of acid made use of in the *reprise*, or second operation; its concentration; and the time during which it is applied. From experiment it has been shown, that each of these unfavorable circumstances might easily occasion a loss of from the half of a thirty-second part of a carat, to two thirty-second parts. The assayers explain their technical language by observing, that in the whole mass consisting of twenty-four carats, this thirty-second part denotes 1-768th part of the mass. It may easily be conceived, therefore, that if the whole six circumstances were to exist, and be productive of errors, falling the same way, the loss would be very considerable.

It is therefore indispensably necessary, that one uniform process should be followed in the assays of gold; and it is a matter of astonishment, that such an accurate process should not have been prescribed by government for assayers, in an operation of such great commercial importance, instead of every one being left to follow his own judgment. The process recommended in the old French official report is as follows:—twelve grains of the gold intended to be assayed must be mixed with thirty grains of fine silver, and cupelled with 108 grains of lead. The cupellation must be carefully attended to, and all the imperfect buttons rejected. When the cupellation is ended, the button must be reduced, by lamination, into a plate of 1½ inches, or rather more, in length, and four or five lines in breadth. This must be rolled up upon a quill, and placed in a matrass capable of holding about three ounces of liquid, when filled up to its narrow part. Two ounces and a half of very pure aquafortis, of the strength of 20 degrees of Baumé's areometer, must then be poured upon it; and the matrass being placed upon hot ashes, or sand, the acid must be kept gently boiling for a quarter of an hour: the acid must then be cautiously decanted, and an additional quantity of 1½ ounces must be poured upon the metal, and slightly boiled for twelve minutes. This being likewise carefully decanted, the small spiral piece of metal must be washed with filtered river water, or distilled water, by filling the matrass with this fluid. The vessel is then to be reversed, by applying the extremity of its neck against the bottom of a crucible of fine earth, the internal surface of which is very smooth. The annealing must now be made, after having separated the portion of water which had fallen into the crucible; and, lastly, the annealed gold must be weighed. For the certainty of this operation, two assays must be made in the same manner, together with a third assay upon gold of twenty-four carats, or upon gold the fineness of which is perfectly and generally known.

No conclusion must be drawn from this assay, unless the latter gold should prove to be of the fineness of twenty-four carats exactly, or of its known degree of fineness; for, if there be either loss or surplus, it may be inferred that the other two assays, having undergone the same operation, must be subject to the same error. The operation being made according to this process by several assayers, in circumstances of importance, such as those which relate to large fabrications, the fineness of the gold must not be depended upon, nor considered as accurately known, unless all the assayers have obtained a uniform result, without communication with each other. This identity must be considered as referring to the accuracy of half the thirty-second part of a carat. For, notwithstanding every possible precaution or uniformity, it very seldom happens that an absolute agreement is obtained between the different assays of one and the same ingot; because the ingot itself may differ in its fineness in different parts of its mass.

The phenomena of the cupellation of gold are the same as of silver, only the operation is less delicate, for no gold is lost by evaporation or penetration into the bone-ash, and therefore it bears safely the highest heat of the assay furnace. The button of gold never vegetates, and need not therefore be drawn out to the front of the muffle, but may be left at the further end till the assay is complete. Copper is retained more strongly by gold than it is by silver; so that with it 16 parts of lead are requisite to sweat out 1 of copper; or, in general, twice as much lead must be taken for the copper alloys of gold, as for those of silver. When the copper is alloyed with very small quantities of gold, cupellation would afford very uncertain results; we must then have recourse to liquid analysis.

M. Vauquelin recommends to boil 60 parts of nitric acid at 22° Baumé, on the spiral slip or cornet of gold and silver alloy, for twenty-five minutes, and replace the liquid afterwards by acid of 32°, which must be boiled on it for eight minutes. This process is free from uncertainty when the assay is performed upon an alloy containing a considerable quantity of copper. But this is not the case in assaying finer gold; for then a little silver always remains in the gold. The surcharge which occurs here is 2 or 3 thousandths; this is too much, and it is an intolerable error when it becomes greater, which often happens. This evil may be completely avoided by employing the following process of M. Chaudet. He takes 0·500 of the fine gold to be assayed; cupels it with 1·500 of silver, and 1·000 of lead; forms, with the button from the cupel, a riband or strip three inches long, which he rolls into a cornet. He puts this into a matrass with acid at 22° B., which he boils for 3 or 4 minutes. He replaces this by acid of 32° B., and boils for ten minutes; then decants off, and boils again with acid of 32°, which must be finally boiled for 8 or 10 minutes.

Gold thus treated is very pure. He washes the cornet, and puts it entire into a small crucible permeable to water; heats the crucible to dull redness under the muffle, when the gold assumes the metallic lustre, and the cornet becomes solid. It is now taken out of the crucible and weighed.

When the alloy contains platinum, the assay presents greater difficulties. In general, to separate the platinum from the gold with accuracy, we must avail ourselves of a peculiar property of platinum; when alloyed with silver, it becomes soluble in nitric acid. Therefore, by a proper quartation of the alloy by cupellation, and boiling the button with nitric acid, we may get a residuum of pure gold. If we were to treat the button with sulphuric acid, however, we should dissolve nothing but the silver. The copper is easily removed by cupellation. Hence, supposing that we have a quaternary compound of copper, silver, platinum, and gold, we first cupel it, and weigh the button obtained; the loss denotes the copper. This button, treated by sulphuric acid, will suffer a loss of weight equal to the amount of silver present. The residuum, by quartation with silver and boiling with nitric acid, will part with its platinum, and the gold will remain pure. For more detailed explanations, see Platinum.

ATOMIC WEIGHTS or ATOMS, are the primal quantities in which the different objects of chemistry, simple or compound, combine with each other, referred to a common body, taken as unity. Oxygen is assumed by some philosophers, and hydrogen by others, as the standard of comparison. Every chemical manufacturer should be thoroughly acquainted with the combining ratios, which are, for the same two substances, not only definite, but multiple; two great truths, upon which are founded not merely the *rationale* of his operations, but also the means of modifying them to useful purposes. The discussion of the doctrine of atomic weights, or prime equivalents, belongs to pure chemistry; but several of its happiest applications are to be found in the processes of art, as pursued upon the greatest scale. For many instructive examples of this proposition, the various chemical manufactures may be consulted in this Dictionary.

ATROPIA; a vegetable alkali extracted from the *Atropa belladonna*, or deadly night-shade. It is composed of about 70·98 carbon, 7·83 hydrogen, 4·83 azote, and 16·36 oxygen in 100 parts. It is prepared by treating the expressed juice of the fresh plant, or watery extract of the dry, with caustic soda unto slight alkaline reaction, and then agitating the mixture with one and a half times its volume of ether. The atropia is taken up by the ether, but again deposited from it when the ethereous solution is left at rest for some time. The treatment with ether is repeated upon the first precipitate, till the atropia becomes pure. Other processes are prescribed.

ATTAR OF ROSES. See Oils, Volatile, and Perfumery.

AURUM MUSIVUM. Mosaic gold, a preparation of tin; which see.

AUTOMATIC, a term which I have employed to designate such economic arts as are carried on by self-acting machinery. The word "manufacture," in its etymological sense, means any system or objects of industry executed by the hands; but in the vicissitude of language, it has now come to signify every extensive product of art which is made by machinery, with little or no aid of the human hand, so that the most perfect manufacture is that which dispenses entirely with manual labor.* It is in our modern cotton and flax mills that automatic operations are displayed to most advantage; for there the elemental powers have been made to animate millions of complex organs, imparting to forms of wood, iron and brass, an intelligent agency. And as the philosophy of the fine arts, poetry, painting, and music, may be best studied in their individual masterpieces, so may the philosophy of manufactures in these its noblest creations.†

The constant aim and effect of these automatic improvements in the arts are philanthropic, as they tend to relieve the workman either from niceties of adjustment, which exhaust his mind and fatigue his eyes, or from painful repetition of effort, which distort and wear out his frame. A well arranged power-mill combines the operation of many work-people, adult and young, in tending with assiduous skill a system of productive machines continuously impelled by a central force. How vastly conducive to the commercial greatness of a nation, and the comforts of mankind, human industry can become, when no longer proportioned in its results to muscular effort, which is by its nature fitful and capricious, but when made to consist in the task of guiding the work of mechanical fingers and arms regularly impelled, with equal precision and velocity, by some indefatigable physical agent, is apparent to every visitor of our cotton, flax, silk, wool, and machine factories. This great era in the useful arts is mainly due to the genius of Arkwright. Prior to the introduction of his system, manufactures were every where feeble and fluctuating in their development, shooting forth luxuriantly for a season, and again withering almost to the roots like annual plants. Their perennial growth then began, and attracted capital, in copious streams, to irrigate the rich domains of industry. When this new career commenced, about the year 1770, the annual consumption of cotton in British manufactures was under four millions of pounds' weight, and that of the whole of Christendom was probably not more than ten millions. In 1850 the consumption in Great Britain and Ireland was about five hundred and eighty-eight millions of pounds, and that of Europe and the United States together one thousand and ninety-two millions. In our spacious factory apartments the benignant power of steam summons around him his myriads of willing menials, and assigns to each the regulated task, substituting for painful muscular effort upon their part, the energies of his own gigantic arm, and demanding in return, only attention and dexterity to correct such little aberrations as casually occur in his workmanship. Under his auspices and in obedience to Arkwright's polity, magnificent edifices, surpassing far in number, value, usefulness, and ingenuity of construction, the boasted monuments of Asiatic, Egyptian, and Roman despotism, have, within the short period of fifty years, risen up in this kingdom, to show to what extent capital, industry, and science, may augment the resources of a state, while they meliorate the condition of its citizens. Such is the automatic system, replete with prodigies in mechanics and political economy, which promises, in its future growth, to become the great minister of civilization to the terraqueous globe, enabling this country, as its heart, to diffuse, along with its commerce, the life-blood of knowledge and religion to myriads of people still lying "in the region and shadow of death."* Of these truths, the present work affords decisive evidence in almost every page.

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* Philosophy of Manufactures, p. 1.

† Ibid., p. 2.

AUTOMATON. In the etymological sense, this word (self-working) signifies every mechanical construction which, by virtue of a latent intrinsic force, not obvious to common eyes, can carry on, for some time, certain movements more or less resembling the results of animal exertion, without the aid of external impulse. In this respect, all kinds of clocks and watches, planetariums, common and smoke jacks, with a vast number of the machines now employed in our cotton, silk, flax, and wool factories, as well as in our dyeing and calico printing works, may be denominated automatic. But the term, automaton, is, in common language, appropriated to that class of mechanical artifices in which the purposely concealed power is made to imitate the arbitrary or voluntary motions of living beings. Human figures, of this kind, are sometimes styled *Androides*, from the Greek term, *like a man.*

Although, from what we have said, clock-work is not properly placed under the head automaton, it cannot be doubted that the art of making clocks, in its progressive improvement and extension, has given rise to the production of automata. The most of these, in their interior structure, as well as in the mode of applying the moving power, have a distinct analogy with clocks; and these automata are frequently mounted in connexion with watch work. Towards the end of the 13th century, several tower clocks, such as those at Strasburg, Lubec, Prague, Olmutz, had curious mechanisms attached to them. The most careful historical inquiry proves that automata, properly speaking, are certainly not older than *wheel*-clocks; and that the more perfect structures of this kind are subsequent to the general introduction of *spring*-clocks. Many accounts of ancient automata, such as the flying doves of Archytas of Tarentum, Regiomontanus's iron flies, the eagle which flew towards the emperor Maximilian, in Nuremburg, in the year 1470, were deceptions, or exaggerated statements; for, three such masterpieces of art would form now, with every aid of our improved mechanisms, the most difficult of problems. The imitation of flying creatures is extremely difficult, for several reasons. There is very little space for the moving power, and the only material possessed of requisite strength being metal, must have considerable weight. Two automata, of the celebrated French mechanician, Vaucauson, first exhibited in the year 1738, have been greatly admired; namely, a flute-player, five and a half feet high, with its cubical pedestal, which played several airs upon the German flute; and that, not by any interior tube-work, but through the actual blowing of air into the flute, the motion of the tongue, and the skilful stopping of the holes with the fingers; as also a duck, which imitated many motions of a natural kind in the most extraordinary manner. This artist has had many imitators, of whom the brothers Droz of Chaux de Fonds were the most distinguished. Several very beautiful clock mechanisms of theirs are known. One of them with a figure which draws; another playing on the piano; a third which writes, besides numerous other combined automata. Frederick Von Knauss completed a writing machine at Vienna, in the year 1760. It is now in the model cabinet of the Polytechnic Institute, and consists of a globe 2 feet in diameter, containing the mechanism, upon which a figure 7 inches high sits, and writes upon a sheet of paper fixed to a frame, whatever has been placed beforehand upon a regulating cylinder. At the end of every line, it rises and moves its hand sideways, in order to begin a new line.

Very complete automata have not been made of late years, because they are very expensive; and by soon satisfying curiosity, they cease to interest. Ingenious mechanicians find themselves better rewarded by directing their talents to the self-acting machinery of modern manufactures. We may notice here, however, the mechanical trumpeter of Mälzl, at Vienna, and a similar work of Kauffmann, at Dresden. In French Switzerland some artists continue to make minute automata which excite no little wonder; such as singing canary birds, with various movements of a natural kind; also little birds, sometimes hardly three-quarters of an inch long, in snuff-boxes and watches of enamelled gold. Certain artificial figures which have been denominated automata, hardly deserve the name; since trick and confederacy are more or less concerned in their operation. To this head belong a number of figures apparently speaking by mechanism; a clock which begins to strike, or to play, when a person makes a sign of holding up his finger; this effect being probably produced by a concealed green-finch, or other little bird, instructed to set off the *détente* of the wheel-work at a signal. It is likely, also, that the chess player of Von Kempelen, which excited so much wonder in the last century, had a concealed confederate. Likewise, the very ingenious little figures of Tendler, father and son, which imitated English horsemen and rope-dancers, constructed at Eisenerz, in Styria, are probably no more true automata than the *fantoccini*, or figures of puppets which are exhibited in great perfection in many towns of Italy, especially at Rome.

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* Philosophy of Manufactures, p. 18

The moving power of almost all automata is a wound-up steel spring; because in comparison with other means of giving motion, it takes up the smallest room, is easiest concealed, and set a-going. Weights are seldom employed, and only in a partial way. The employment of other moving powers is more limited; sometimes fine sand is made to fall on the circumference of a wheel, by which the rest of the mechanism is moved. For the same purpose water has been employed; and, when it is made to fall into an air-chamber, it causes sufficient wind to excite musical sounds in pipes. In particular cases quicksilver has been used, as, for example, in the Chinese tumblers, which is only a physical apparatus to illustrate the doctrine of the centre of gravity.

Figures are frequently constructed for playthings which move by wheels hardly visible. An example of this simplest kind of automaton which may be introduced here, as illustrating the self-acting principles of manufactures, is shown in the figure.

Fig. 102 exhibits the outlines of an automaton, representing a swan, with suitably combined movements. The mechanism may be described, for the sake of clearness of explanation, under distinct heads. The first relates to the motion of the whole figure. By means of this part it swims upon the water, in directions changed from time to time without exterior agency. Another construction gives to the figure the faculty of bending its neck on several occasions, and to such an extent that it can plunge the bill and a portion of the head under water. Lastly, it is made to move its head and neck slowly from side to side.

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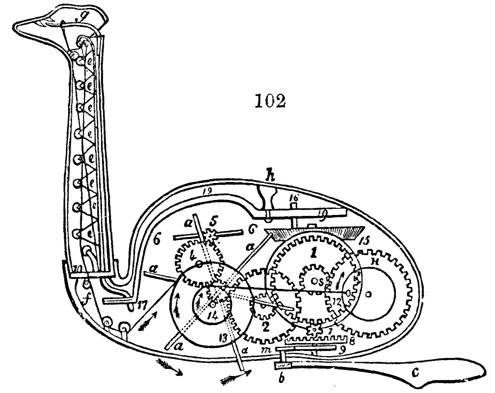

On the barrel of the spring, exterior to the usual ratchet wheel, there is a main-wheel, marked 1, which works into the pinion of the wheel 2. The wheel 2 moves a smaller one, shown merely in dotted lines, and on the long axis of the latter, at either end there is a rudder, or water-wheel, the paddles of which are denoted by the letter *a*. Both of these rudder-wheels extend through an oblong opening in the bottom of the figure down into the water. They turn in the direction of the arrow, and impart a straight-forward movement to the swan. The chamber, in which these wheels revolve, is made water tight, to prevent moisture being thrown upon the rest of the machinery. By the wheel 4, motion is conveyed to the fly-pinion 5; the fly itself 6, serves to regulate the working of the whole apparatus, and it is provided with a stop bar not shown in the engraving, to bring it to rest, or set it a-going at pleasure. Here, as we may imagine, the path pursued is rectilinear, when the rudder-wheels are made to work in a square direction. An oblique bar, seen only in section at *b*, moveable about its middle point, carries at each end a web foot *c*, so that the direction of the bar *b*, and of both feet towards the rudder wheels, determines the form of the path which the figure will describe. The change of direction of that oblique bar is effected without other agency. For this purpose, the wheel 1 takes into the pinion 7 and this carries round the crown-wheel 8, which is fixed, with an eccentric disc 9, upon a common axis. While the crown-wheel moves in the direction of the arrow, it turns the smaller eccentric portion of the elliptic disc towards the lever *m*, which, pressed upon incessantly by its spring, assumes, by degrees, the position corresponding with the middle line of the figure, and afterwards an oblique position; then it goes back again, and reaches its first situation; consequently through the reciprocal turning of the bar *h*, and the swim-foot, is determined and varied the path which the swan must pursue. This construction is available with all automata, which work by wheels; and it is obvious, that we may, by different forms of the disc 9, modify, at pleasure, the direction and the velocity of the turnings. If the disc is a circle, for instance, then the changes will take place less suddenly; if the disc has an outward and inward curvature, upon whose edge the end of the lever presses with a roller, the movement will take place in a serpentine line.

The neck is the part which requires the most careful workmanship. Its outward case must be flexible, and the neck itself should therefore be made of a tube of spiral wire, covered with leather, or with a feathered bird-skin. The double line in the interior, where we see the triangles *e*, *e*, *e*, denotes a steel spring made fast to the plate 10, which forms the bottom of the neck; it stands loose, and needs to be merely so strong as to keep the neck straight, or to bend it a little backwards. It should not be equally thick in all points, but it should be weaker where the first graceful bend is to be made; and, in general, its stiffness ought to correspond to the curvature of the neck of this bird. The triangles *e* are made fast at their base to the front surface of the spring; in the points of each there is a slit, in the middle of which a moveable roller is set, formed of a smoothly turned steel rod. A thin catgut string *f*, runs from the upper end of the spring, where it is fixed over all these rollers, and passes through an aperture pierced in the middle of 10, into the inside of the rump. If the catgut be drawn straight back towards *f*, the spring, and consequently the neck, must obviously be bent, and so much the more, the more tightly *f* is pulled, and is shortened in the hollow of the neck. How this is accomplished by the wheel-work will presently be shown. The wheel 11 receives its motion from the pinion *s*, connected with the main-wheel 1. Upon 11 there is, moreover, the disc 12, to whose circumference a slender chain is fastened. When the wheel 11 turns in the direction of the arrow, the chain will be so much pulled onwards through the corresponding advance at the point at 12, till this point has come to the place opposite to its present situation, and, consequently, 11 must have performed half a revolution. The other end of the chain is hung in the groove of a very moveable roller 14; and this will be turned immediately by the unwinding of the chain upon its axis. There turns, in connexion with it, however, the large roller 13, to which the catgut *f* is fastened; and as this is pulled in the direction of the arrow, the neck will be bent until the wheel 11 has made a half revolution. Then the drag ceases again to act upon the chain and the catgut; the spring in the neck comes into play: it becomes straight, erects the neck of the animal, and turns the rollers 13 and 14, back into their first position.

The roller 13 is of considerable size, in order that through the slight motion of the roller 14, a sufficient length of the catgut may be wound off, and the requisite shortening of the neck may be effected; which results from the proportion of the diameters of the rollers 11, 13, and 14. This part of the mechanism is attached as near to the side of the hollow body as possible, to make room for the interior parts, but particularly for the paddle-wheels. Since the catgut, *f*, must pass downwards on the middle from 10, it is necessary to incline it sideways and outwards towards 13, by means of some small rollers.

The head, constituting one piece with the neck, will be depressed by the complete flexure of this; and the bill, being turned downwards in front of the breast, will touch the surface of the water. The head will not be motionless; but it is joined on both sides by a very moveable hinge, with the light ring, which forms the upper part of the clothing of the neck. A weak spring, *g*, also fastened to the end of the neck, tends to turn the head backwards; but in the present position it cannot do so, because a chain at *g*, whose other end is attached to the plate 10, keeps it on the stretch. On the bending of the neck, this chain becomes slack; the spring *g* comes into operation, and throws the head so far back, that, in its natural position, it will reach the water.

Finally, to render the turning of the head and the neck practicable, the latter is not closely connected with the rump, while the plate 10 can turn in a cylindrical manner upon its axis, but cannot become loose outwardly. Moreover, there is upon the axis of the wheel 1, and behind it (shown merely as a circle in the engraving) a bevel wheel, which works into a second similar wheel, 15, so as to turn it in a horizontal direction. The pin 16, of the last wheel, works upon a two-armed lever 19, moveable round the point *h*, and this lever moves the neck by means of the pin 17. The shorter arm of the

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lever 19 has an oval aperture in which the pin 16 stands. As soon as this, in consequence of the movement of the bevel-wheel 15, comes into the dotted position, it pushes the oval ring outwards on its smaller diameter, and thereby turns the lever upon the point *h*, into the oblique direction shown by the dotted lines. The pin 16, having come on its way right opposite to its present position, sets the lever again straight. Then the lever, by the further progress of the pin in its circular path, is directed outwards to the opposite side; and, at last, when 15 has made an entire revolution, it is quite straight. The longer arm of the lever follows, of course, these alternating movements, so that it turns the neck upon its plate 10, by means of the pin 17; and, as 18 denotes the bill, this comes into the dotted position. It may be remarked in conclusion, that the drawing of *fig.* 102 represents about half the size of which the automaton may be constructed, and that the body may be formed of thin sheet-copper or brass.

Fig. 103, 104, 105, show the plan of a third automaton; a horse which moves its feet in a natural way, and draws a carriage with two figures sitting in it. The man appears to drive the horse with a whip; the woman bends forward from him in front. The four wheels of the carriage have no connexion with the moving mechanism. In *fig.* 105, some parts are represented upon a larger scale. The wheel 1, in *fig.* 103, operates through the two carrier wheels upon the wheels marked 4 and 5. By means of the axis of these two wheels, the feet are set in motion. The left fore-foot, *a*, then the right hinder foot, move themselves backwards, and take hold of the ground with small tacks in their hoofs, while the two other legs are bent and raised, but no motion of the body takes place. The carriage, however, with which the horse is connected, advances upon its wheels. By studying the mechanism of the foot, *a*, and the parts connected with it, we can readily understand the principles of the movement. The axis of wheel 4 is crank-shaped on both sides, where it has to operate directly on the fore feet; but for each foot, it is bent in an opposite direction, as is obvious in the front view *fig.* 104. This crank, or properly its part furthest from the axis, serves instead of the pin 16, in the swan, and moves like it in an oval spot, *p*, *fig.* 103, a two-armed lever, which gives motion through tooth-work, but not as in the swan, by means of a second pin. This wheel-work renders the motion smoother. The above lever has its fulcrum at *n*, *fig.* 103, about which it turns alternately, to the one and the other side, by virtue of the rotation of the wheel 4. The toothed arch, or the half-wheel on the under side, lays hold of a shorter lever, in a similar arch, upon the upper joint of the foot, which is moved forward and backward upon the pivot *m*. In virtue of the motions in the direction of the arrow, the foot *a* will move itself first obliquely backwards, without bending, and the body will thereby bend itself forward. When the right hand foot makes the same motion, both the other feet are raised and bent. The joints of the foot at *d* and *e* are formed of hinges, which are so constructed that they can yield no farther than is necessary at every oblique position of the foot. With the continued rotation of the wheel 4, the lever turns itself about *n*, in an inverted direction inwards, and impels the uppermost foot-joint forward, so that it forms an acute angle with the body in front. The foot is now twice bent upon its joints. This takes place by the traction of the chain *t*, which is led over rollers (as the drawing shows) to the foot, and is there fastened. As its upper end has its fixed point in the interior of the body, it is therefore drawn by the eccentric pin *r* standing in the vicinity of *m*, and thus bends the foot at the hinges. If there was space for it, a roller would answer better than a pin. By

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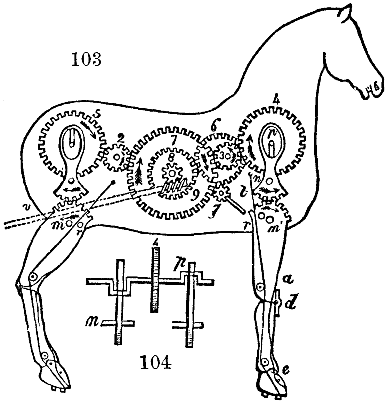

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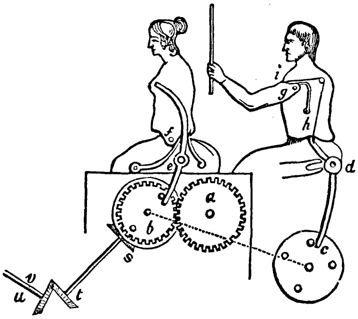

the recedure of the uppermost joint into the first position, the tension of the chain *t* ceases again of itself, while the pin *r* removes from it, and the foot is again extended in a straight line by the small springs operating upon its two under parts, which were previously bent stiffly by the chain. By the aid of the figures with this explanation, it will be apparent that all the fore feet have a similar construction, that the proper succession of motions will be effected through toothed arcs, and the position of the cranks on the axis of the wheels 4 and 5, and hence the advance of the figure must follow. The wheel 6 puts the fly 7 in motion, by means of the small wheel marked 1; on the fixed points of the 4 chains, by means of a ratchet-wheel and a catch, the necessary tension will again be produced when the chains have been drawn out a little. There is sufficient room for a mechanism which could give motion to the head and ears, were it thought necessary.

The proper cause of the motions may now be explained. In *fig.* 105, *a*, is a wheel connected with the wound-up spring, by which the motion of the two human figures, and also, if desired, that of the horse may be effected. The axis of the wheel *b* carries a disc with pins, which operate upon the two-armed lever with its fulcrum *e*, and thus causes the bending of the upper part of one of the figures, which has a hinge at *f*. On the axis of that wheel there is a second disc *c*, for giving motion to the other figure; which, for the sake of clearness, is shown separate, although it should sit alongside of its fellow. On the upper end of the double-armed lever *d*, there is a cord whose other end is connected with the moving arm, in the situation *i*, and raises it whenever a pin in the disc presses the under part of the lever. A spring *h* brings the arm back into the original position, when a pin has passed from the lever, and has left it behind. The pins at *c* and *d* may be set at different distances from the middle of the disc, whereby the motions of the figures by every contact of another pin, are varied, and are therefore not so uniform, and consequently more natural.

For the connection of both mechanisms, namely, the carriage with the horse, various arrangements may be adopted. Two separate traction springs should be employed; one at *a*, *fig.* 105, in the coach-seat; the other in the body of the horse. In the coach-seat at *b*, the fly with its pinion, as well as a ratchet-wheel, is necessary. By means of the shaft, the horse is placed in connection with the wagon. It may, however, receive its motion from the spring in the carriage, in which case one spring will be sufficient. Upon the latter plan the following construction may be adopted:—To the axis of *b*, *fig.* 105, a bevel wheel is to be attached, and from this the motion is to be transmitted to the bottom of the carriage with the help of a second bevel wheel *s*, connected with a third bevel wheel *t*. This again turns the wheel *u*, whose long axis *v* goes to the middle of the horse's body, in an oblique direction, through the hollow shaft. This axis carries an endless screw 9, *fig.* 103, with very oblique threads, which works into the little wheel 8, corresponding to the wheel 1, through an opening in the side of the horse, and in this way sets the mechanism of the horse a-going. With this construction of *fig.* 105, a spring of considerable strength is necessary, or if the height of the carriage-seat does not afford sufficient room, its breadth will answer for placing two weaker springs alongside of each other upon a common barrel.

AVENTURINE. According to Wöhler's examination, aventurine glass owes its golden iridescence to a crystalline separation of metallic copper from the mass colored brown by the peroxide of iron.

In the aventurine glaze for porcelain a crystalline separation of green oxide of chromium from the brown ferruginous mass of the glaze produces a similar effect. This glaze is prepared as follows:

31	parts of fine	lixiviated	dry porcelain earth from Halle,
43	do.	do.	dry quartz sand,
14	do.	do.	gypsum,
12	do.	do.	fragments of porcelain,

are stirred up with 300 parts of water, and by repeated straining through a linen sieve uniformly suspended in it, and intimately mixed. To this paste is added, under constant agitation and one after the other, aqueous solutions of

19	parts	bichromate of potash,
100	"	protosulphate of iron,
47	"	acetate of lead,

and then so much solution of ammonia that the iron is completely separated. The salts of potash and ammonia are removed by frequent decantation with spring water.

The baked porcelain vessels are dipped into the pasty mixture obtained as above described in the same manner as with other glazes, and then fired in the porcelain furnace. After this they appear covered with a brown glaze, which in reflected light appears to be filled with a countless number of light gold spangles.

A thin fragment of the glass appears, under the microscope, by transmitted light, as a clear brownish glass, in which numerous transparent green six-sided prisms of oxide of chromium, and some brownish crystals, probably of oxide of chromium and peroxide of iron, are suspended. The oxide of chromium therefore separates, on the slow cooling of the glaze in the porcelain furnace, from the substance of the glaze—a silicate of potash, lime, and alumina—saturated with the peroxide of iron, and shines through the brownish mass with a golden color. When the aventurine glaze is mixed with an equal amount of colorless porcelain glaze, the glassy mass no longer has a brown color after the burning, but a light greenish-gray, and the eliminated crystalline spangles likewise exhibit in reflected light their natural green color.

AXE. A tool much used by carpenters for cleaving, and roughly fashioning, blocks of wood. It is a flat iron wedge, with an oblong steel edge, parallel to which, in the short base, is a hole for receiving and holding fast the end of a strong wooden handle. In the cooper's *adze*, the oblong edge is at right angles to the handle, and is slightly curved up, or inflected towards it.

AXLES, of carriages.—See WHEEL CARRIAGES.

AXUNGE. Hog's lard; see FAT and OILS.

AZOBENZOIDE, and AZOBENZOYLE, products of the action of pure water of ammonia upon oil of bitter almonds, by making the ammonia pass down through a wide tube filled with the almond pap. The operation must be continued for weeks.

AZOTIZED, said of certain vegetable substances, which, as containing azote, were supposed at one time to partake, in some measure, of the animal nature; most animal bodies being characterized by the presence of much azote in their composition. The vegetable products, indigo, cafeine, gluten, and many others, contain abundance of azote.

AZURE, the fine blue pigment, commonly called smalt, is a glass, colored with oxide of cobalt, and ground to an impalpable powder.

The manufacture of azure, or smalt, has been lately improved in Sweden, by the adoption of the following process:—

The cobalt ore is first roasted till the greater part of the arsenic is driven off. The residuary impure black oxide is mixed with as much sulphuric acid (concentrated) as will make it into a paste, which is exposed at first to a moderate heat, then to a cherry-red ignition for an hour. The sulphate thus obtained is reduced to powder, and dissolved in water. To the solution, carbonate of potash is gradually added, in order to separate the remaining portion of oxide of iron; the quantity of which depends upon the previous degree of calcination. If it be not enough oxidized, the iron is difficult to be got rid of.

When, from the color of the precipitate, we find that the potash separates merely carbonate of cobalt, it is allowed to settle, the supernatant liquor is decanted, and precipitated, by means of a solution of silicate of potash, prepared as follows:—

Ten parts of potash are carefully mixed with fifteen parts of finely ground flints or sand, and one part of pounded charcoal. This mixture is melted in a crucible of brick clay, an operation which requires steady ignition during 5 or 6 hours. The mass, when melted and pulverized, may be easily dissolved in boiling water, adding to it, by little at a time, the glass previously ground. The filtered solution is colorless, and keeps well in the air, if it contains one part of glass for 5 or 6 of water. The silicate of cobalt which precipitates upon mixing the two solutions, is the preparation of cobalt most suitable for painting upon porcelain, and for the manufacture of blue glass. See COBALT.

B.

BABLAH. The rind or shell which surrounds the fruit of the *mimosa cineraria*; it comes from the East Indies, as also from Senegal, under the name of Neb-neb. It contains gallic acid, tannin, a red coloring matter, and an azotized substance; but the proportion of tannin is smaller than in sumach, galls, and *knoppern* (gall-nuts of the common oak) in reference to that of gallic acid, which is considerable in the bablah. It has been used, in dying cotton, for producing various shades of drab; as a substitute for the more expensive astringent dye-stuffs.

BAGASSE. The sugar-cane, in its dry, crushed state, as delivered from the sugar-mill. It is much employed for fuel in the colonial sugar-houses.

BAKING. (*Cuire*, Fr. *Backen*, Germ.) The exposure of any body to such a heat as will dry and consolidate its parts without wasting them. Thus wood, pottery, and porcelain, are baked, as well as bread.

BALANCE.—To conduct arts, manufacturers, and mines, with judgment and success, recourse must be had, at almost every step, to a balance. Experience proves that all material bodies, existing upon the surface of the earth, are constantly solicited by a force which tends to bring them to its centre, and that they actually fall towards it

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when they are free to move. This force is called gravity. Though the bodies be not free, the effort of gravity is still sensible, and the resultant of all the actions which it exercises upon their material points constitutes what is popularly called their *weight*. These weights are, therefore, forces which may be compared together, and by means of machines may be made to correspond or be counterpoised.

To discover whether two weights be equal, we must oppose them to each other in a machine where they act in a similar manner, and then see if they maintain an equilibrium; for example, we fulfil this condition if we suspend them at the two extremities of a lever, supported at its centre, and whose arms are equal. Such is the general idea of a balance. The beam of a good balance ought to be a bar of well-tempered steel, of such form as to secure perfect inflexibility under any load which may be fitly applied to its extremities. Its arms should be quite equal in weight and length upon each side of its point of suspension; and this point should be placed in a vertical line over the centre of gravity; and the less distant it is from it, the more delicate will be the balance. Were it placed exactly in that centre, the beam would not spontaneously recover the horizontal position when it was once removed from it. To render its indications more readily commensurable, a slender rod or needle is fixed to it, at right angles, in the line passing through its centres of gravity and suspension. The point, or rather edge of suspension, is made of perfectly hard steel, and turns upon a bed of the same. For common uses the arms of a balance can be made sufficiently equal to give satisfactory results; but, for the more refined purposes of science, that equality should never be presumed nor trusted to; and, fortunately, exact weighing is quite independent of that equality. To weigh a body is to determine how many times the weight of that body contains another species of known weight, as of grains or pounds, for example. In order to find it out, let us place the substance, suppose a piece of gold, in the left hand scale of the balance; counterpoise it with sand or shot in the other, till the index needle be truly vertical, or stand in the middle of the scale, proving the beam to be horizontal. Now remove gently the piece of gold, and substitute in its place standard multiple weights of any graduation, English or French, till the needle again resumes the vertical position, or till its oscillations upon either side of the zero point are equal. These weights will represent precisely the weight of the gold, since they are placed in the same circumstances precisely with it, and make the same equilibrium with the weight laid in the other scale.

This method of weighing is obviously independent of the unequal length as well as the unequal weight of the arms of the beam. For its perfection two requisites only are indispensable. The first is that the points of suspension should be rigorously the same in the two operations; for the power of a given weight to turn the beam being unequal, according as we place it at different distances from the centre of suspension, did that point vary in the two consecutive weighings, we would require to employ, in the second, a different weight from that of the piece of gold, in order to form an equilibrium with the sand or shot originally put in the opposite scale; and as there is nothing to indicate such inequality in the states of the beam, great errors would result from it. The best mode of securing against such inequality is to suspend the cords of the scales from sharp-edged rings, upon knife edges, at the ends of the beam, both made of steel so hard tempered as to be incapable of indentation. The second condition is, that the balance should be very sensible, that is, when in equilibrium and loaded, it may be disturbed, and its needle may oscillate, by the smallest weight put into either of the scales. This sensibility depends solely upon the centre or nail of suspension; and it will be the more perfect the less friction there is between that *knife-edge* surface and the plane which supports it. Both should therefore be as hard and highly polished as possible; and should not be suffered to press against each other, except at the time of weighing. Every delicate balance of moderate size, moreover, should be suspended within a glass case, to protect it from the agitations of the air, and the corroding influence of the weather. In some balances a ball is placed upon the index or needle (whether that index stand above or below the beam), which may be made to approach or recede from the beam by a fine-threaded screw, with the effect of varying the centre of gravity relatively to the point of suspension, and thereby increasing, at will, either the sensibility, or the stability of the balance. The greater the length of the arms, the less distant the centre of gravity is beneath the centre of suspension, the better polished its central knife-edge of 30°, the lighter the whole balance, and the less it is loaded, the greater will be its sensibility. In all cases the arms must be quite inflexible. A balance made by Ramsden for the Royal Society is capable of weighing ten pounds, and turns with one hundredth of a grain, which is the seven-millionth part of the weight. In pointing out this balance to me one evening, Dr. Wollaston told me it was so delicate, that Mr. Pond, then astronomer royal, when making some observations with it, found its indications affected by his relative position before it, although it was inclosed in a glass case. When he stood opposite the right arm, that end of the beam preponderated, in consequence of its becoming expanded by the radiation of heat from his body; and when he stood opposite the left arm, he made this preponderate in its turn. It is probable that Mr. Pond had previously adjusted the centres of gravity and suspension so near to each other as to give the balance its maximum sensibility, consistent with stability. Were these centres made to coincide, the beam, when the weights are equal, would rest in any position, and the addition of the smallest weight would overset the balance, and place the beam in a vertical position, from which it would have no tendency to return. The sensibility in this case would be the greatest possible; but the other two requisites of level and stability would be entirely lost. The case would be even worse if the centre of gravity were higher than the centre of suspension, as the balance when deranged, if free, would make a revolution of no less than a semi-circle. A balance may be made by a fraudulent dealer to weigh falsely though its arms be equal, provided the suspension be as low as the centre of gravity, for he has only to toss his tea, for instance, forcibly into one scale to cause 15 ounces of it, or thereby, to counterpoise a pound weight in the other. Inspectors of weights, &c., are not *au fait* to this fruitful source of fraud among hucksters.

BALANCE FOR WEIGHING COIN at the Bank of England, invented by William Cotton, Esq., Governor of the Bank.

The new coinage first arrives at the Bank from the Mint in what are called "journies," a single journey weighing 15 lbs," and containing 701 sovereigns. The officers of the Mint are allowed 12 grains *plus* in every pound weight of metal, for the irregularities incidental to working it into coin; but they usually work to within one half of that allowance, which is technically called "the remedy."

There was coined for the Bank in the spring of 1843, 8,000,000 of sovereigns, and the greatest variation from the weight allowed was only 60 grains, or one third of the remedy. Each sovereign should contain a portion of this remedy, to allow for wear in public use; and this extraordinary subdivision of metal is invariably obtained. The usual delivery of new coinage at the Bank contains 100 journies, which is counted by weight only, that is, 200 sovereigns are counted into one scale, and the rest of the delivery is weighed in parcels which balance these 200, and this is all the counting the new coinage receives. The regularity and precision of the manipulations at the Mint obviate the necessity of any further examination, either as regards the gross amount or the weight of an individual piece.

When the currency returns to the Bank from the public, it becomes necessary to ascertain if it has been reduced below the standard weight, and this imposes an arduous duty on the officers of the Bank. The amount of gold paid daily over the Bank counter varies considerably, but 30,000 may be taken as a rough average; and hence arises a tedious, irksome, and expensive process in weighing so large a number of pieces singly, and in quick succession, separating at the same time the light from the standard coin.

The mode of weighing coins by hand requires much dexterity, practice and attention; but, in spite of all these, errors were inevitable, and it was to obviate these that the machine was invented by Mr. Cotton, the Governor of the Bank of England; it was constructed from his plans by Mr. Napier, and is thus described:—

Its exterior presents a plain brass case, with a small hopper tube on the top plate, about 4½ inches from which there is an opening in the top plate. In this opening is seen a platform in the form of a quadrant. This platform is suspended above one end of the beam, and is to receive the coin to be weighed. On one side of the case is a till to receive the sovereigns as they are weighed, partitioned so that one division is left for standard coin, and the other for such as are light. There is a sliding door to each division, for removing the coins at pleasure. The machine may be worked like a clock with a weight, or by any simple application of power.

Its visible action is as follows:—The hopper being filled with gold, upon setting the machine in motion, it immediately places a sovereign on the little platform, which serves, as already stated, in place of a scale plan; and if it is of standard weight a small tongue comes rapidly forward and pushes the sovereign into that side of the till allotted to such coin; if light, another, and similar tongue to the first, pushes the sovereign into the other side of the till. The action of these tongues is at right angles to each other.

While a sovereign is being weighed, a succeeding one is on its way from the hopper to the platform, and the moment the preceding sovereign is disposed of, according to its value, another is placed in its stead. To keep the hopper supplied with gold, and remove it from the till as it is filled, is all the attendance necessary. The more minute parts of the mechanical arrangement of the machine, such as the fulcrum, the forceps, &c., are described in detail; and the following statement by Mr. Miller is given as a comparison with the old method of weighing:—

"With the bullion-scales 4,000 may be stated as the number a person can weigh in six hours. As the sovereigns now tendered at the Bank counter are most of them new, the scale dips quickly in weighing, and one person can weigh 5,000 in six hours; but a short time ago, before the issue of the new coinage, the same person could weigh only 3,000, as it took a longer time for the scales to indicate.

"The bullion scales cannot indicate nearer than 4-100ths of a grain, at the above rate.

"The machine is perfectly free from the sources of error to which the scales are subject, and weighs as quickly, whether the sovereigns are new and of full weight, or old and doubtful; it can weigh 10,000 in six hours, and divide coin varying only one-fiftieth of a grain."

The paper is illustrated by two drawings of the internal arrangement of the machine, and a model, showing the action of the tongues and platform.

Mr. Oldham exhibited, at the Institute of Civil Engineers, the automaton balance at work, weighing coin, and after describing, with the aid of a diagram and model, the action of some of the more delicate parts of the machine, he observed, that in seeking to obtain extraordinary performances by machinery mechanical propriety of construction was too often overlooked, and premature deterioration, in the action of many parts, was the result.

The automaton balance was peculiarly worthy of notice, from the judgment exercised in its relative proportions, as was proved by the fact that after being at work for several months, it had become more delicate in detecting slight variations between standard and light coin, than when it was first constructed. Mr. Cotton's object in this invention should be well understood. Public convenience demanded great accuracy in weighing the currency: by the ordinary mode of weighing gold with the bullion scales, although it was due to the banktellers to state that they gave the utmost attention to their monotonous duty, it was nearly impossible to guard against the various difficulties detailed in the paper. The injury sustained by the optic nerve, from constantly watching the indicator of the scales, was a serious inconvenience to the operative, which, coupled with the incidental sources of error referred to, created even greater absence of delicacy than the papers stated. Errors to the amount of one-third, or even half a grain, were not unfrequent.

By the "automaton balance," the number weighed in a given time was increased, and undeviating accuracy obtained. The delicacy of the instrument was such, that from thirty to thirty-five coins per minute could be passed through the machine, detecting a difference of only one-fifth of a grain.

It should be mentioned, that much greater delicacy could be accomplished; that is, to the one-hundredth of a grain, but not at the same rate; because it would be understood that a slow action of the beam was necessary for very small variations, and that must regulate the speed of working; but such delicacy was beyond all useful purposes in those transactions which it was intended to improve.

Mr. Cotton said that his attention had been attracted to the point by the inconveniences to which the "tellers" were subjected in weighing gold for the public; with balances so delicately constructed as the bullion-scales, the agitation of the air, by the sudden opening of a door, or even by the breathing of those around, sufficed to cause errors. It was possible, also, by pressing the fulcrum against the bridle, to produce such a degree of friction as materially to interfere with accuracy; and the tellers confessed that after weighing two or three thousand coins, the sight was injured, and they no longer observed with the same degree of correctness. He therefore imagined that a machine might be contrived, which, being defended from external influence, might weigh coins as fast as by hand, and within one-fourth of a grain; but he certainly did not contemplate attaining such perfection as the machine now possessed. His first idea was, that the light coins should be taken off by forceps, and that those of average weight should be pushed off by the succeeding ones; but it was found that the slightest inaccuracy in the milled edges sufficed to give them a wrong direction; therefore when he had made the first rough sketch, and consulted with his friend, the late Mr. Ewart, he recommended that Mr. Napier, of York Road, Lambeth, should be employed to make the machine, and to him was due the suggestion of the two alternately advancing tongues, as well as several other arrangements of the machinery, which he had so successfully constructed.

When the first machine was tried, out of 1000 sovereigns 160 were found to be light. They were given to a teller to be verified, and he returned several of them as being of the proper weight; but, on again weighing them more carefully, the results given by the machine were found to be correct. As an instance of how many circumstances should be taken into consideration in delicate machines, he might mention, that after being used for a time, the machine varied in its results, and, on examination, it was discovered, that the end of the lever which traversed the pendant had become magnetic, and thus affected the balance. An ivory end was substituted, and ever since that period its accuracy had been maintained.

Mr. W. Miller observed that the efficiency of any scales must be determined, in a great degree, by the fineness of the edge of the fulcrum of the beam; and it would be easily imagined that the friction, to which the edge in a pair of bullion scales was subjected, whilst weighing 5000 or 6000 sovereigns per day, must soon impair its delicacy, and consequently the efficiency of the whole apparatus; for, whether the sovereigns were light or heavy, the beam must turn upon its fulcrum. Such was not the case with Mr. Cotton's machine; its beam did not act at all, unless a light sovereign was placed upon the platform; so that, among 1000 sovereigns, if only 100 were light, the beam of the machine would only move 100 times, while that of the ordinary scales would oscillate 1000 times. An immense advantage was thus given to the machine in point of durability.

All weighing was but an approach to correctness, and the nearest point to which the best kind of common scales were sensible, might be stated as $\frac{3}{100}$ths of a grain, and ¼th of a grain would hardly cover their errors; but the machine was sensible to $\frac{5}{100}$ths of a grain, and $\frac{3}{100}$ths would fully cover its errors, which were not a twentieth part so numerous as those of the scales.

BALSAMS (*Baumes*, Fr. *Balsame*, Germ.) are native compounds of ethereal or essential oils, with resin, and frequently benzoic acid. Most of them have the consistence of honey; but a few are solid, or become so by keeping. They flow either spontaneously, or by incisions made from trees and shrubs in tropical climates. They possess peculiar powerful smells, aromatic hot tastes, but lose their odoriferous properties by long exposure to the air. They are insoluble in water; soluble, to a considerable degree, in ether; and completely in alcohol. When distilled with water, ethereal oil comes over, and resin remains in the retort.

1. Balsams with benzoic acid :—

Balsam of Peru is extracted from the *myroxylon peruiferum*, a tree which grows in Peru, Mexico, &c.; sometimes by incision, and sometimes by evaporating the decoction of the bark and branches of the tree. The former kind is very rare, and is imported in the husk of the cocoa-nut, whence it is called balsam *en coque*. It is brown, transparent only in thin layers, of the consistence of thick turpentine; an agreeable smell, an acrid and bitter taste; formed of two matters, the one liquid, the other granular, and somewhat crystalline. In 100 parts, it contains 12 of benzoic acid, 88 of resin, with traces of a volatile oil.

The second sort, the *black* balsam of Peru, is much more common than the preceding, translucent, of the consistence of well-boiled sirup, very deep red-brown color, an almost intolerably acrid and bitter taste, and a stronger smell than the other balsam. Stoltze regards it as formed of 69 parts of a peculiar oil, 20·7 of a resin, little soluble in alcohol, of 6·4 of benzoic acid, of 0·6 of extractive matter, and 0·9 of water.

From its high price, balsam of Peru is often adulterated with copaiba, oil of turpentine, and olive oil. One thousand parts of good balsam should, by its benzoic acid, saturate 75 parts of crystallized carbonate of soda. It is employed as a perfume for pomatums, tinctures, lozenges, sealing-wax, and for chocolate and *liqueurs*, instead of vanilla, when this happens to be very dear

Liquid amber, Storax or Styrax, flows from the leaves and trunk of the *liquid amber styraciflua*, a tree which grows in Virginia, Louisiana, and Mexico. It is brownish ash-gray, of the consistence of turpentine, dries up readily, smells agreeably, like benzoin, has a bitterish, sharp, burning taste; is soluble in 4 parts of alcohol, and contains only 1·4 per cent. of benzoic acid.

Balsam of Tolu flows from the trunk of the *myroxylon toluiferum*, a tree which grows in South America; it is, when fresh, of the consistence of turpentine, is brownish-red, dries into a yellowish or reddish brittle resinous mass, of a smell like benzoin; is soluble in alcohol and ether; affords, with water, benzoic acid.

Chinese varnish flows from the bark of the *Augia sinensis;* it is a greenish yellow turpentine-like substance, smells aromatic, tastes strong and rather astringent, in thin layers dries soon into a smooth shining lac, and consists of resin, ethereous oil, and benzoic acid. It is soluble in alcohol and ether; and has been employed, immemorially, in China, for lackering and varnishing surfaces, either alone or colored.

Balsams without benzoic acid :—

Copaiva balsam, balsam of copahu or capivi, is obtained from incisions made in the trunk of the *Copaifera officinalis*, a tree which grows in Brazil and Cayenne. It is pale yellow, middling liquid, clear transparent, has a bitter, sharp, hot taste; a penetrating disagreeable smell; a specific gravity of from 0·950 to 0·996. It dissolves in absolute alcohol, partially in spirit of wine, forms with alkalis, crystalline compounds. It consists of 45·59 ethereous oil, 52·75 of a yellow brittle resin, and 1·66 of a brown viscid resin. The oil contains no oxygen, has a composition like oil of turpentine, dissolves caoutchouc (according to Durand), but becomes oxydized in the air, into a peculiar species of resin. This balsam is used for making paper transparent, for certain lackers, and in medicine.

This substance, which is extensively used in medicine, is often adulterated. Formerly some unctuous oil was mixed with it, but as this is easily discovered by its insolubility in alcohol, castor oil has since been used. The presence of this cheaper oil may be detected, 1, by agitating the balsam with a solution of caustic soda, and setting the mixture aside to repose; when the balsam will come to float clear on the top, and leave a soapy thick magma of the oil below; 2, when the balsam is boiled with water, in a thin film, for some hours, it will become a brittle resin on cooling, but it will remain viscid if mixed with castor oil; 3, if a drop of the oil on white paper be held over a lamp, at a proper distance, its volatile oil will evaporate and leave the brittle resin, without causing any stain around, which the presence of oil will produce; 4, when three drops of the balsam are poured into a watch-glass, alongside of one drop of sulphuric acid, it becomes yellow at the point of contact, and altogether of a saffron hue when stirred about with a glass rod, but if sophisticated with castor oil, the mixture soon becomes nearly colorless like white honey, though after some time the acid blackens the whole in either case; 5, if 3 parts in bulk of the balsam be mixed with 1 of good water of ammonia (of 0·970 sp. grav.) in a glass tube, it will form a transparent solution, if it be pure, but will form a white liniment if it contains castor oil; 6, if the balsam be triturated with a little of the common magnesia alba, it will form a clear solution, from which acids dissolve out the magnesia, and leave the oil transparent, if it be pure, but opaque if it be adulterated. When turpentine is employed to falsify the balsam, the fraud is detected by the smell on heating the compound.

Mecca balsam, or opobalsam, is obtained both by incisions of, and by boiling, the branches and leaves of the *Balsamodendron Gileadense,* a shrub which grows in Arabia Felix, Lesser Asia, and Egypt. When fresh it is turbid, whitish, becomes, by degrees, transparent; yellow, thickish, and eventually solid. It smells peculiar, but agreeable; tastes bitter and spicy; does not dissolve completely in hot spirit of wine, and contains 10 per cent. of ethereous oil, of the specific gravity 0·876.

Japan lac varnish flows from incisions in the trunk of the *Rhus Vernix* (*Melanorrhea usitata*) which is cultivated in Japan, and grows wild in North America. The juice becomes black in the air; when purified, dissolves in very little oil; and, mixed with coloring matter, it constitutes the celebrated varnish of the Japanese.

For Benzoin and Turpentine, see these articles in their alphabetical places.

BANDANNA. A style of calico printing, in which white or brightly colored spots are produced upon a red or dark ground. It seems to have been practised from time immemorial in India, by binding up firmly with thread, those points of the cloth which were to remain white or yellow, while the rest of the surface was freely subjected to the dyeing operations.

The European imitations have now far surpassed, in the beauty and precision of the design, the oriental patterns; having called into action the refined resources of mechanical and chemical science. The general principles of producing bright figures upon dark grounds, are explained in the article CALICO-PRINTING; but the peculiarities of the Bandanna printing may be conveniently introduced here. In Brande's Journal for July, 1823, I described the Bandanna gallery of Messrs. Monteith at Glasgow, which, when in full action some years ago, might be reckoned the most magnificent and profitable printing apartment in the world. The white spots were produced by a solution of chlorine, made to percolate down through the Turkey red cotton cloth, in certain points defined and circumscribed by the pressure of hollow lead types in plates, in a hydraulic press. *Fig.* 106 is an elevation of one press; A, the top or entablature; B B, the cheeks or pillars; C, the upper block for fastening the upper lead perforated pattern to; D, the lower block to which the fellow pattern is affixed, and which moves up and down with the piston of the press; E, the piston or ram; F, the sole or base; G, the water-trough, for the discharged or spotted calico to fall into; H, the small cistern, for the aqueous chlorine or liquor-meter, with glass tubes for indicating the height of liquor inside of the cistern; *e e,* glass stopcocks, for admitting the liquor into that cistern from the general reservoir; *f f,* stopcocks for admitting water to wash out the chlorine; *g g,* the pattern lead-plates, with screws for setting the patterns parallel to each other; *m m,* projecting angular pieces at each corner, perforated with a half-inch hole to receive the four guide-pins rising from the lower plate, which serve to secure accuracy of adjustment between the two faces of the lead pattern plates; *h h,* two rollers which seize and pull through the discharged pieces, and deliver them into the water-trough. To the left of D there is a stopcock for filling the trough with water; *l,* is the waste tube for chlorine liquor and water of washing. The contrivance for blowing a stream of air across the cloth, through the pattern tubes, is not represented in the figure.

Sixteen engines similar to the above, each possessing the power of pressing with several hundred tons, are arranged in one line, in subdivisions of four; the spaces

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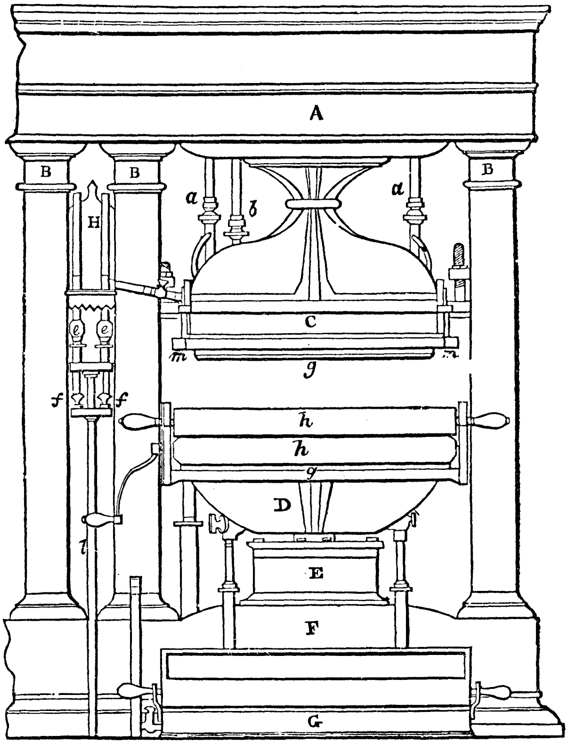

between each subdivision serving as passages to allow the workmen to go readily from the front to the back of the presses. Each occupies twenty-five feet, so that the total length of the apartment is 100 feet.

To each press is attached a pair of patterns in lead, (or plates, as they are called,) the manner of forming which will be described in the sequel. One of these plates is fixed to the upper block of the press. This block is so contrived, that it rests upon a kind of universal joint, which enables this plate to apply more exactly to the under fellow-plate. The latter sits on the moveable part of the press, commonly called the sill. When this is forced up, the two patterns close on each other very nicely, by means of the guide-pins at the corners, which are fitted with the utmost care.

The power which impels this great hydrostatic range is placed in a separate apartment, called the machinery room. This machinery consists of two press cylinders of a peculiar construction, having solid rams accurately fitted to them. To each of these cylinders, three little force-pumps, worked by a steam-engine, are connected.

The piston of the large cylinder is eight inches in diameter, and is loaded with a top-weight of five tons. This piston can be made to rise about two feet through a leather stuffing or collar. The other cylinder has a piston of only one inch in diameter, which is also loaded with a top-weight of five tons. It is capable, like the other, of being raised two feet through its collar.

Supposing the pistons to be at their lowest point, four of the six small force-pumps are put in action by the steam-engine, two of them to raise the large piston, and two the little one. In a short time, so much water is injected into the cylinders, that the loaded pistons have arrived at their highest points. They are now ready for working the hydrostatic discharge-presses, the water pressure being conveyed from the one apartment to the other, under ground, through strong copper tubes, of small calibre.

Two valves are attached to each press, one opening a communication between the large driving-cylinder and the cylinder of the press, the other between the small driving-cylinder and the press. The function of the first is simply to lift the under-block of the press into contact with the upper-block; that of the second, is to give the requisite compression to the cloth. A third valve is attached to the press, for the purpose of discharging the water from its cylinder, when the press is to be relaxed, in order to remove or draw through the cloth.

From twelve to fourteen pieces of cloth, previously dyed Turkey-red, are stretched over each other, as parallel as possible, by a particular machine. These parallel layers are then rolled round a wooden cylinder, called by the workmen, a drum. This cylinder is now placed in its proper situation at the back of the press. A portion of the fourteen layers of cloth, equal to the area of the plates, is next drawn through between them, by hooks attached to the two corners of the webs. On opening the valve connected with the eight-inch driving-cylinder, the water enters the cylinder of the press, and instantly lifts its lower block, so as to apply the under plate with its cloth, close to the upper one. This valve is then shut, and the other is opened. The pressure of five tons in the one inch prime-cylinder, is now brought to bear on the piston of the press, which is eight inches in diameter. The effective force here will, therefore, be 5 tons $\times 8^2=320$ tons; the areas of cylinders being to each other, as the squares of their respective diameters. The cloth is thus condensed between the leaden pattern-plates with a pressure of 320 tons, in a couple of seconds; —a splendid example of automatic art.

The next step, is to admit the blanching or discharging liquor (aqueous chlorine, obtained by adding sulphuric acid to solution of chloride of lime) to the cloth. This liquor is contained in a large cistern, in an adjoining house, from which it is run at pleasure into small lead cisterns H attached to the presses; which cisterns have graduated index tubes, for regulating the quantity of liquor according to the pattern of discharge. The stopcocks on the pipes and cisterns containing this liquor, are all made of glass.

From the measure-cistern H, the liquor is allowed to flow into the hollows in the upper lead-plate, whence it descends on the cloth, and percolates through it, extracting in its passage the Turkey-red dye. The liquor is finally conveyed into the waste pipe, from a groove in the under block. As soon as the chlorine liquor has passed through, water is admitted in a similar manner, to wash away the chlorine; otherwise, upon relaxing the pressure, the outline of the figure discharged would become ragged. The passage of the discharge liquor, as well as of the water through the cloth, is occasionally aided by a pneumatic apparatus, or blowing machine; consisting of a large gasometer, from which air subjected to a moderate pressure may be allowed to issue, and act in the direction of the liquid upon the folds of the cloth. By an occasional twist of the air stopcock, the workman also can ensure the equal distribution of the discharging liquor, over the whole excavations in the upper plate. When the demand for goods is very brisk, the air apparatus is much employed, as it enables the workman to double his product.

The time requisite for completing the discharging process in the first press is sufficient to enable the other three workmen to put the remaining fifteen presses in play. The discharger proceeds now from press to press, admits the liquor, the air, and the water; and is followed at a proper interval by the assistants, who relax the press, move forwards another square of the cloth, and then restore the pressure. Whenever the sixteenth press has been liquored, &c., it is time to open the first press. In this routine, about ten minutes are employed; that is, 224 handkerchiefs (16+14) are discharged every ten minutes. The whole cloth is drawn successively forward, to be successively treated in the above method.

When the cloth escapes from the press, it is passed between the two rollers in front; from which it falls into a trough of water placed below. It is finally carried off to the washing and bleaching department, where the lustre of both the white and the red is considerably brightened.

By the above arrangement of presses, 1600 pieces, consisting of 12 yards each=19,200 yards, are converted into Bandannas in the space of ten hours, by the labor of four workmen.

The patterns, or plates, which are put into the presses to determine the white figures on the cloth, are made of lead in the following way. A trellis frame of cast-iron, one inch thick, with turned-up edges, forming a trough rather larger than the intended lead pattern, is used as the solid ground-work. Into this trough, a lead plate about one half inch thick, is firmly fixed by screw nails passing up from below. To the edges of this lead plate, the borders of the piece of sheet-lead are soldered, which covers the whole outer surface of the iron frame. Thus a strong trough is formed, one inch deep. The upright border gives at once great strength to the plate, and serves to confine the liquor. A thin sheet of lead is now laid on the thick lead-plate, in the manner of a veneer on toilet-tables, and is soldered to it round the edges. Both sheets must be made very smooth beforehand, by hammering them on a smooth stone table, and then finishing with a plane: the surface of the thin sheet (now attached) is to be covered with drawing paper, pasted on, and upon this the pattern is drawn. It is now ready for the cutter. The first thing which he does is to fix down with brass pins all the parts of the pattern which are to be left solid. He now proceeds with the little tools generally used by block-cutters, which are fitted to the different curvatures of the pattern, and he cuts perpendicularly quite through the thin sheet. The pieces thus detached are easily lifted out; and thus the channels are formed which design the white figures on the red cloth. At the bottom of the channels, a sufficient number of small perforations are made through the thicker sheet of lead, so that the discharging liquor may have free ingress and egress. Thus, one plate is finished, from which an impression is to be taken by means of printers' ink, on the paper pasted upon another plate. The impression is taken in the hydrostatic press. Each pair of plates constitutes a set, which may be put into the presses, and removed at pleasure.

BARBERRY. The root of this plant contains a yellow coloring matter, which is soluble in water and alcohol, and is rendered brown by alkalis. The solution is employed in the manufacture of Morocco leather.

BARILLA. A crude soda, procured by the incineration of the *salsola soda*, a plant cultivated for this purpose in Spain, Sicily, Sardinia, &c. Good barilla usually contains, according to my analysis, 20 per cent. of real alkali, associated with muriates and sulphates, chiefly of soda, some lime, and alumina, with very little sulphur. Caustic leys made from it were used in the finishing process of the hard soap manufacture.

The quantity of barilla and alkali imported in 1850 amounted to 34,880 cwts., and in 1851 to 45,740 cwts. The quantity of soda exported in 1850 was 827,403 cwts., and in 1851, 839,183 cwt.; the declared value being respectively 375,351*l.*, and 360,565*l.* There is no duty on barilla.

BARIUM. The metallic basis of Baryta.

BARK, the outer rind of plants. Many varieties of barks are known to commerce, but the term is commonly used to express either Peruvian or Jesuits' bark, a most valuable pharmaceutical remedy, or Oak bark, which is very extensively used by tanners and dyers. The quantity of this article imported for the use of the latter amounted in 1850 to 380,674 cwts., and in 1851 to 460,895 cwts. The duty on bark has been repealed.

BARLEY. (*Orge*, Fr.; *Gerste*, Germ.) English barley is that with two-rowed ears, or the *hordeum vulgare distichon* of the botanists; the Scotch beer or bigg is the *hordeum vulgare hexastichon.* The latter has two rows of ears, but 3 corns come from the same point, so that it seems to be six-eared. The grains of bigg are smaller than those of barley, and the husks thinner. The specific gravity of English barley varies from 1·25 to 1·33; of bigg from 1·227 to 1·265; the weight of the husk of barley is one-sixth, that of bigg two-ninths. 1000 parts of barley flour contain, according to Einhof, 720 of starch. 56 sugar, 50 mucilage, 36·6 gluten, 12·3 vegetable albumen, 100 water, 2·5 phosphate of lime, 68 fibrous or ligneous matter. Sp. gravity of barley is 1·235 by my trials.

BARM. The yeasty top of fermenting beer. See Beer, Distillation, Fermentation.

BARYTA or BARYTES, one of the simple earths. It may be obtained most easily by dissolving the native carbonate of barytes (Witherite) in nitric acid, evaporating the neutral nitrate till crystals be formed, draining and then calcining these, by successive portions, in a covered platina crucible, at a bright red heat. A less pure baryta may be obtained by igniting strongly a mixture of the carbonate and charcoal, both in fine powder and moistened. It is a grayish white earthy looking substance, fusible only at the jet of the oxy-hydrogen blowpipe, has a sharp caustic taste, corrodes the tongue and all animal matter, is poisonous even in small quantities, has a very powerful alkaline reaction; a specific gravity of 4·0; becomes hot, and slakes violently when sprinkled with water, falling into a fine white powder, called the hydrate of baryta, which contains 10½ per cent. of water, and dissolves in 10 parts of boiling water. This solution lets fall abundant columnar crystals of hydrate of baryta as it cools; but it still retains one-twentieth its weight of baryta, and is called baryta water. The above crystals contain 61 per cent. of water, of which, by drying, they lose 50 parts. This hydrate may be fused at a red heat without losing any more water. Of all the bases, baryta has the strongest affinity for sulphuric acid, and is hence employed either in the state of the above water, or in that of one of its neutral salts, as the nitrate or muriate, to detect the presence and determine the quantity of that acid present in any soluble compound. Its prime equivalent is 7·66, hydrogen being 1,000. Native sulphate of baryta, or heavy spar, is fraudulently used to adulterate white lead by the English dealers to a shameful extent.

BASSORINE. A constituent part of a species of gum which comes from Bassora, as also of gum tragacanth, and of some gum resins. It is semi-transparent, difficult to pulverize, swells considerably in cold or boiling water, and forms a thick mucilage without dissolving. Treated with ten times its weight of nitric acid, it affords nearly 23 per cent. of its weight of mucic acid, being much more than is obtainable from gum arabic or cherry-tree gum. Bassorine is very soluble in water slightly acidulated with nitric or muriatic acid. This principle is procured by soaking gum Bassora in a great quantity of cold water, and in removing, by a filter, all the soluble parts.

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BATHS. (*Bains*, Fr.; *Baden*, Germ.) Warm baths have lately come into very general use, and they are justly considered as indispensably necessary in all modern houses of any magnitude, as also in club-houses, hotels, and hospitals. But the mode of constructing these baths, and of obtaining the necessary supplies of hot and cold water, does not appear to have undergone an improvement equal to the extension of their employment.

The several points in regard to warm baths, are,

1. The materials of which they are constructed.
2. Their situation.
3. The supply of cold water.
4. The supply of hot water.
5. Minor comforts and conveniences.

1. As to the materials of which they are constructed.—Of these the best are slabs of polished marble, properly bedded with good water-tight cement, in a seasoned wooden case, and neatly and carefully united at their respective edges. These, when originally well constructed, form a durable, pleasant, and agreeable-looking bath; but the expense is often objectionable, and, in upper chambers, the weight may prove inconvenient. If of white or veined marble, they are also apt to get yellow or discolored by frequent use, and cannot easily be cleansed; so that large Dutch tiles, as they are called, or square pieces of white earthenware, are sometimes substituted; which, however, are difficultly kept water-tight; so that, upon the whole, marble is preferable. Welsh slate has now superseded marble to a great extent.

Where there are reasons for excluding marble, copper, tinned, or galvanized iron is the usual material resorted to. The first is most expensive in the outfit, but far more durable than the latter, which are, moreover, liable to leakage at the joints, unless most carefully made. Either the one or the other should be well covered outside and inside with several coats of paint, which may then be marbled or otherwise ornamented.

Wooden tubs, square or oblong, and oval, are sometimes used for warm baths; and are cheap and convenient, but neither elegant nor cleanly. The wood always contracts a mouldy smell; and the difficulty and nuisance of keeping them water-tight, and preventing shrinkage, are such as to exclude them from all except extemporaneous application.

2. As to the situation of the bath, or the part of the house in which it is to be placed.—In hotels and club-houses this is a question easily determined: several baths are usually here required, and each should have annexed to it a properly warmed dressing-room. Whether they are up stairs or down stairs is a question of convenience, but the basement story, in which they are sometimes placed, should always be avoided: there is a coldness and dampness belonging to it, in almost all weathers, which is neither agreeable nor salubrious.

In hospitals, there should be at least two or three baths on each side of the house (the men's and women's), and the supply of hot water should be ready at a moment's notice. The rooms in which the baths are placed should be light, and comparatively large and airy; and such conveniences for getting into and out of the baths should be adopted as the sick are well known to require. The dimensions of these baths should also be larger than usual.

In private houses, the fittest places for warm baths are dressing-rooms annexed to the principal bed-rooms; or, where such convenience cannot be obtained, a separate bath-room, connected with the dressing-room, and always upon the bed-room floor. All newly-built houses should be properly arranged for this purpose, and due attention should be paid to the warming of the bath-room, which ought also to be properly ventilated. A temperature of 70° may be easily kept up in it, and sufficient ventilation is absolutely requisite to prevent the deposition of moisture upon the walls and furniture.

The objection which formerly prevailed, in respect to the difficulty of obtaining adequate supplies of water, in the upper rooms, has been entirely obviated by having cisterns at or near the top of the house; and we would just hint that these should be so contrived as to be placed out of the reach of frost; a provision of the utmost importance in every point of view, and very easily effected in a newly-built house, though it unfortunately happens that architects usually regard these matters as trifles, and treat them with neglect, as indeed they do the warming and ventilation of buildings generally.

3. The supply of water of proper quality and quantity is a very important point, as connected with the present subject. The water should be soft, clean, and pure, and as free as possible from all substances mechanically suspended in it. In many cases it answers to dig a well for the exclusive supply of a large house with water. In most parts of London this may effectually be accomplished at a comparatively moderate expense; and, if the well be deep enough, the water will be abundant, soft, and pellucid. The labor of forcing it by a pump to the top of the house is the only drawback; this,

however, is very easily done by a horse-engine, or there are people enough about town glad to undertake it at a shilling a day. I am led to these remarks by observing the filthy state of the water usually supplied, at very extravagant rates, by the water companies. It deposits its nastiness in the pipes connected with warm baths, and throws down a slippery deposit upon the bottom of the vessel itself, to such an extent as often to preclude its being used, at least as a luxury, which a clear and clean bath really is. This inconvenience may, in some measure, be avoided by suffering the water to throw down its extraneous matters upon the bottom of the cistern, and drawing our supplies from pipes a little above it; there will, however, always be more or less deposit in the pipes themselves, and every time the water runs into the cistern the grouts are stirred up and diffused through its mass.

4. and 5.—In public bathing establishments, where numerous and constant baths are required, the simplest and most effective means of obtaining hot water for their supply consists in drawing it directly into the baths from a large boiler, placed somewhere above their level. This boiler should be supplied with proper feeding-pipes and gauges; and, above all things, its dimensions should be ample; it should be of wrought iron or copper. The hot water should enter the bath by a pipe at least an inch and a half in diameter; and the cold water by one of the same dimensions, or somewhat larger, so that the bath may not be long in filling. The relative proportions of the hot and cold water are, of course, to be adjusted by a thermometer, and every bath should have a two-inch waste-pipe, opening about two inches from the top of the bath, and suffering the excess of water freely to run off; so that when a person is immersed in the bath, or when the supplies of water are accidentally left open, there may be no danger of an overflow.

When there is a laundry in the upper story of the house, or other convenient place for erecting a copper and its appurtenances, a plan similar to the above may often be conveniently adopted in private houses, for the supply of a bath upon the principal bed-room floor. An attempt is sometimes made to place boilers behind the fires of dressing-rooms, or otherwise to erect them in the room itself, for the purpose of supplying warm water; but this plan is always objectionable from the complexity of the means by which the supply of water is furnished to the boiler, and often dangerous from the flues becoming choked with soot and taking fire. Steam is also apt, in such cases, to escape in quantities into the room; so that it becomes necessary to search for other methods of heating the bath; one or two of the least objectionable of which I shall describe.

(1.) A contrivance of some ingenuity consists in suffering the water for the supply of the bath to flow from a cistern above it, through a leaden pipe of about one inch diameter, which is conducted into the kitchen or other convenient place, where a large boiler for the supply of hot water is required. The bath-pipe is immersed in this boiler, in which it makes many convolutions, and, again emerging, ascends to the bath. The operation is simply this:—the cold water passing through the convolutions of that part of the pipe which is immersed in the boiling water, receives there sufficient heat for the purpose required, and is delivered in that state by the ascending pipe into the bath, which is also supplied with cold water and waste-pipes as usual. The pipe may be of lead, as far as the descending and ascending parts are concerned, but the portion forming the worm or convolutions immersed in the boiler should be copper, in order that the water within it may receive heat without impediment.

This plan is economical only where a large boiler is constantly kept at work in the lower part of the house; otherwise the trouble and expense of heating such a boiler, for the mere purpose of the bath, render it unavailable. The worm-pipe is also apt to become furred upon the outside by the deposition of the earthy impurities of the water in which it is immersed; it then becomes a bad conductor of heat, is cleansed with difficulty, and the plan is rendered ineffective. This system, however, has been adopted, in some particular cases, with satisfaction.

(2.) A much more simple, economical, and independent mode of heating a warm bath, by a fire placed at a distance from it, is the following, which is found to answer perfectly in private houses, as well as upon a more extended scale in large establishments. It is certainly open to some objections, but these are overbalanced by its advantages. A wagon-shaped boiler, holding about six gallons of water, is properly placed over a small furnace in any convenient and safe part of the house, as the kitchen, scullery, servants' hall, or wash-house. The bath itself, of the usual dimensions and construction, is placed where it is wanted, with a due supply of cold water from above. Two pipes issue from within an inch of the bottom of the bath at its opposite extremities; one at the head of the bath, about one inch, and the other at the foot, an inch and one-eighth in diameter. These tubes descend to the boiler, the smaller one entering it at the bottom, and the larger one issuing from its top.

Under these circumstances, supposing the pipes and boiler everywhere perfectly tight, when the bath is filled, the water will descend into and expel the air from the boiler, and completely fill it. Now upon making a gentle fire under the boiler, an ascending current of warm water will necessarily pass upwards through the larger pipe which issues from its top, and cold water will descend by the pipe which enters at the bottom; and thus, by the establishment of currents, the whole mass of water in the bath will become heated to the desired point; or, if above it, the temperature may easily be lowered by the admixture of cold water.

The advantages of this form of bath are numerous. The shorter the pipes of communication the better, but they may extend forty or fifty feet without any inconvenience beyond that of expense; so that there is no obstacle to the bath being near the bed-room while the boiler is on the basement story. There is but little time required for heating the bath; the water in which may, if requisite, be raised to about 100° in about half an hour from the time of lighting the fire. The consumption of fuel is also trifling.

The following are the chief disadvantages attendant upon this plan, and the means of obviating them:—

It is necessary, when the water has acquired its proper temperature, to arrest the circulation of the water by means of a stopcock or valve adjoining the boiler; the next resource is to withdraw the fire from the boiler, or not to use the bath immediately, as it may go on acquiring some heat from the boiler, so that we may become inconveniently hot in the bath. When, therefore, this bath is used, we may proceed as follows:—Heat the water in it an hour before it is wanted, to about 100°, and then extinguish the fire. The water will retain its temperature, or nearly so, for three or four hours, especially if the bath be shut up with a cover; so that when about to use it, cold water may be admitted till the temperature is lowered to the required point, and thus all the above inconveniences are avoided.

Another disadvantage of this bath arises from too fierce a fire being made under the boiler, so as to occasion the water to boil within it, a circumstance which ought always to be carefully avoided. In that case, the steam rising in the upper part of the boiler, and into the top pipe, condenses there, and occasions violent concussions, the noise of which often alarms the whole house, and leads to apprehensions of explosion, which, however, is very unlikely to occur; but the concussions thus produced injure the pipes, and may render them leaky; so that in regard to these, and all other baths, &c., we may remark, that the pipes should pass up and down in such parts of the house as will not be injured if some leakage takes place; and under the bath itself should be a sufficiently large leaden tray with a waste-pipe, to receive and carry off any accidental drippings, which might injure the ceilings of the rooms below. In all newly-built houses, two or three flues should be left in proper places for the passage of ascending and descending water-pipes; and these flues should in some way receive at their lower part a little warm air in winter, to prevent the pipes freezing; the same attention should also be paid to the situation of the cisterns of water in houses, which should be kept within the house, and always supplied with a very ample waste-pipe, to prevent the danger of overflow. Cisterns thus properly placed, and carefully constructed, should be supplied from the water-mains by pipes kept under ground, till they enter the house, and not carried across the area, or immediately under the pavement, where they are liable to freeze.

(3.) Baths are sometimes heated by steam, which has several advantages; it may either be condensed directly into the water of the bath, or, if the bath be of copper or tinned iron, it may be conducted into a casing upon its outside, usually called a jacket; in the latter case there must be a proper vent for the condensed water, and for the escape of air and waste steam. Steam is also sometimes passed through a serpentine pipe, placed at the bottom of the bath. But none of these methods are to be recommended for adoption in private houses, and are only advisable in hospitals, or establishments where steam boilers are worked for other purposes than the mere heating of baths.

The French make much more use of hot baths than we do, both as respects health and cleanliness, a fact well illustrated by the following statistics. In the year 1780 the whole public bathing establishments in Paris contained only 250 separate baths; in 1813 they contained 300; in 1832 there were 78 houses fitted up with 2374 fixed baths, and 1059 movable ones for transporting to private houses; and at present new bathing establishments are being mounted from day to day in the several quarters of the capital.

Galvanized iron is now preferred even to copper for making baths, being equally durable and greatly cheaper. Sulphureous baths are made of sheet zinc, for the alkaline sulphurets act very little upon that metal. The form of the baths is usually made ovoid, because this shape requires less water for immersing the human body than the rectangular.

Many copper and tin baths have been lately constructed in London, with a little furnace attached to one end, and surrounded with a case or jacket, into which the water flows and circulates backwards and forwards till the whole mass in the bath gets heated to the due degree. One of the best of these is that constructed by Mr. Benham,

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of Wigmore street. The bath must be placed near the fire-grate, and the smoke-pipe of the attached furnace be conducted up the chimney a certain way to secure a sufficient draught to maintain combustion. The above bath, well managed, heats the water from 50° to 98° in about 20 or 25 minutes, as I have experimentally proved. When the proper temperature is attained, the fire must of course be extinguished.

BDELLIUM. A gum resin, produced by an unknown plant which grows in Persia and Arabia. It comes to us in yellowish or reddish pieces, smells faintly, like myrrh, and consists of 59 resin, 9·2 gum, 30·6 bassorine, and 1·2 ethereous oil.

BEER. (*Bière*, Fr.; *Bier*, Germ.) The fermented infusion of malted barley, flavored with hops, constitutes the best species of beer; but there are many beverages of inferior quality to which this name is given, such as spruce beer, ginger beer, molasses beer, &c.; all of which consist of a saccharine liquor, partially advanced into the vinous fermentation, and flavored with peculiar substances.

The ancients were acquainted with beer, and the Romans gave it the appropriate name of *Cerevisia* (quasi *Ceresas*), as being the product of corn the gift of Ceres. The most celebrated liquor of this kind in the old time, was the *Pelusian* potation, so called from the town where it was prepared at the mouth of the Nile. Aristotle speaks of the intoxication caused by beer; and Theophrastus very justly denominated it the *wine of barley.* We may, indeed, infer from the notices found in historians, that drinks analogous to our beer were in use among the ancient Gauls, Germans, and in fact almost every people of our temperate zone; and they are still the universal beverage in every land where the vine is not an object of rustic husbandry.

The manufacture of beer, or the art of brewing, may be conveniently considered under five heads:—

1. An examination of the natural productions which enter into its composition; or of barley and hops.
2. The changes which barley must undergo to fit it for making beer; or the processes of malting and mashing.
3. The formation of a proper wort from the mashed malt and hops.
4. The fermentation of that wort; and,
5. The fining, ripening, and preservation of the beer.

I. *Of the materials.*

1. Barley, wheat, maize, and several other kinds of corn are capable of undergoing those fermentative changes, by which beer may be made; but the first substance is by far the fittest. There are two species of barley, the *hordeum vulgare* or common barley, having two seeds arranged in a row on its spikes; and the *hordeum hexastichon*, in which three seeds spring from one point, so that its double row has apparently six seeds. The former is the proper barley, and is much the larger sized grain; the latter is little known in England, but is much cultivated in Scotland under the name of *bear* or *bigg;* being a hardy plant adapted to a colder country. The finer the climate in which barley grows, the denser and larger its seed, and the thinner its husk; thus the Norfolk and Suffolk barley is distinguished in these respects from that of Aberdeenshire. Bigg is a less compact grain than barley; the weight of a Winchester bushel (2150·42 cubic inches) of the former is only about 47 lbs., while that of a bushel of the latter is nearly 51 lbs. Their constituents, however, bear much the same proportion to each other.

The quality of barley is proved not only by its density when dry, but by the increase of volume which it acquires when steeped in water. Thus,

100 measures of average English barley thereby swell into 124.
100 — of — Scotch ditto, - - - 121.
100 — of — — bigg or bear, - 118.
Nay, 100 of very fine Suffolk barley have swollen into - 183.
While 100 of an inferior Scotch bigg became no more than - 109.

This circumstance indicates so nearly the probable yield of malt, that it is carefully attended to by the officers of excise, who gauge the steep cistern, and levy their duty in conformity with the largest volume. 100 pounds of good barley become almost one half heavier by the absorption of moisture; and weigh upon an average 147 pounds; the best of course taking up most water.

By chemical analysis barley flour seems to consist of 67·18 parts of hordeine, or starch and gluten intimately combined, 7·29 of vegetable fibre, 1·15 of coagulated albumen, 3·52 parts of gluten, 5·21 of sugar, 4·62 of gum, 0·24 of phosphate of lime, and 9·37 of water. The loss amounted to 1·42. To these principles should be added a peculiar volatile oil of a concrete nature, which is obtained during the process of distilling fermented malt wash. (See Whiskey.) It may also be extracted from barley flour, by the solvent action of alcohol; and never amounts to more than a few parts in the thousand. The husk also contains some of that fetid oil. Proust thought that he had discovered in barley a peculiar principle, to which he gave the name of *hordeine;* and which he separated from starch by the action of both cold and boiling water. He found that by treating barley meal successively with water, he obtained from 89 to 90 parts of a farinaceous substance, composed of from 32 to 33 of starch, and from 57 to 58 of *hordeine*. Einhof obtained from barley seeds, 70·05 of flour, 18·75 of husks or bran, and 11·20 of water.

According to Proust, hordeine is a yellowish powder, not unlike fine saw-dust. It contains no azote, for it affords no ammonia by distillation, and is therefore very dissimilar to gluten. In the germination of barley, which constitutes the process of malting, the proportion of hordeine is greatly diminished by its conversion into sugar and starch. Other chemists suppose that the *hordeine* of Proust is merely a mixture of the bran of the barley with starch and gluten. It is obvious that the subject stands in need of new chemical researches. In barley the husk constitutes from one fourth to one fifth of the whole weight; in oats it constitutes one third; and in wheat one tenth. From the analysis of barley flour recently made, it appears to consist in 1000 parts: of water, 100; albumen, 22·3; sugar, 56; gum or mucilage, 50; gluten, 37·6; starch, 720; phosphate of lime, 2·5.

2. The hop, *humulus lupulus*, the female flowers of the plant. Ives first directed attention to a yellow pulverulent substance which invests the scales of the catkins, amounting to about one eighth of their weight; and referred to it the valuable properties which hops impart to beer. We may obtain this substance by drying the hops at a temperature of 86° F., introducing them into a coarse canvass bag, and shaking it so that the yellow powder shall pass through the pores of the canvass. This powder bears some resemblance to lycopodium. Of the 13 parts in 100 of this powder, 4 parts are foreign matters, derived from the scales of the cones; leaving 9 parts of a peculiar granular substance. When distilled with water, this substance affords two per cent. of its weight ($\frac{2}{10}$ for 100 times the weight of hops) of a volatile colorless oil, to which the plant owes its peculiar aroma. This oil dissolves in water in considerable quantity. It appears to contain sulphur (for it blackens solutions of silver), and also acetate of ammonia. No less than 65 per cent. of the yellow dust is soluble in alcohol. This solution, treated with water and distilled, leaves a resin, which amounts to 52·5 per cent. It has no bitter taste, and is soluble in alcohol and ether. The watery solution from which the resin was separated contains the bitter substance which has been called *lupuline* by Payen and Chevallier, mixed with a little tannin and malic acid. To obtain this in a state of purity, the free acid must be saturated with lime, the solution evaporated to dryness, and the residuum must be treated with ether, which removes a little resin; after which the *lupuline* is dissolved out by alcohol, which leaves the malate of lime. On evaporating away the alcohol, the lupuline remains, weighing from 8·3 to 12·5 per cent. It is sometimes white, or slightly yellowish, and opaque, sometimes orange yellow and transparent. At ordinary temperatures it is inodorous, but when heated strongly it emits the smell of hops. It possesses the characteristic taste and bitterness of the hop. Water dissolves it only in the proportion of 5 per cent., but it thereby acquires a pale yellow color. Lupuline is neither acid nor alkaline; it is acted upon neither by the dilute acids nor alkalis, nor by the solutions of the metallic salts; it is quite soluble in alcohol, but hardly in ether. It contains apparently no azote, for it affords no ammonia by destructive distillation; but only an empyreumatic oil.

The yellow dust of hops contains, moreover, traces of a fatty matter, gum, a small quantity of an azotized substance, and several saline combinations in minute quantity. Boiling water dissolves from 19 to 31 per cent. of the contents of the dust, of which a large proportion is resin. Ives thought that the scales of the catkins of hops, when freed from the yellow powder, contained no principles analogous to it; but Payen and Chevallier have proved the contrary. The cones of hop give up to boiling alcohol 36 per cent. of soluble matter; while the same cones, stripped of their yellow powder, yield only 26 per cent.; and further, these chemists found the same principles in the different parts of the hop, but in different proportions.

The packing of the hop catkins or cones is one of the most important operations towards the preservation of this plant; and is probably the cause of the enormous difference in value between the English and French hops after a few years keeping. The former, at the end of six years, possess still great value, and may be sold as an article only two or three years old; while the latter have lost the greater part of their value in three years, and are no more saleable at the end of four. In France, it is packed merely by tramping it with the feet in sacks. Under this slight pressure, large interstitial spaces are left amid the mass of the hops, through which the air freely circulates, carrying off the essential oil, and oxygenating some of the other proximate principles, so as to render them inert. By the English method, on the contrary, the hops, after being well rammed into strong sacks hung in frames, are next subjected to the action of a hydraulic press. The valuable yellow powder thus enclosed on every side by innumerable compact scales, is completely screened from the contact of the atmosphere, and from all its vicissitudes of humidity. Its essential oil, in particular, the basis of its flavor, is preserved without decay.

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According to the experiments of Chevallier and Payen upon the hops of England, Flanders, the Netherlands, and the department of the Vosges, those of the county of Kent afforded the largest cones, and were most productive in useful secreted and soluble matters. Next to them were the hops of Alost.

The best hops have a golden yellow color, large cones, an agreeable aroma: when rubbed between the hands, they leave yellow traces, powerfully odoriferous, without any broken portions of the plant, such as leaves, stems, and scaly fragments. When alcohol is digested on good hops, from 9 to 12 per cent. of soluble yellow matter may be obtained by evaporating it to dryness. This is a good test of their quality.

The best-flavored and palest hops are packed in sacks of fine canvass, which are called pockets, and weigh about 1½ cwt. each. These are bought by the ale brewer. The stronger-flavored and darker-colored hops are packed in bags of a very coarse texture like door-mats, called hop bags: these contain generally about 3 cwt., and are sold to the porter and beer brewers. After the end of a year or two, hops are reckoned to have lost much of their marketable value, and are then sold to the second-rate porter brewers, under the name of old hops. The finest hops are grown in the neighborhood of Canterbury; but those of Worcester have an agreeable mildness of flavor, greatly admired by many ale drinkers. When the bitter and aromatic principles disappear, the hops are no better than so much chaff; therefore, an accurate chemical criterion of their principles would be a great benefit to the brewer.

II. *Malting.*—This process consists of three successive operations; the steeping; the couching, sweating, and flooring; and the kiln-drying.

The *steeping* is performed in large cisterns made of wood or stone, which being filled with clear water up to a certain height, a quantity of barley is shot into them, and well stirred about with rakes. The good grain is heavy, and subsides; the lighter grains, which float on the surface, are damaged, and should be skimmed off; for they would injure the quality of the malt, and the flavor of the beer made with it. They seldom amount to more than two per cent. More barley is successively emptied into the steep cistern, till the water stands only a few inches, about five, above its surface; when this is levelled very carefully, and every light seed is removed. The steep lasts from forty to sixty hours, according to circumstances; new barley requiring a longer period than old, and bigg requiring much less time than barley.

During this steep, some carbonic acid is evolved from the grains, and combines with the water, which, at the same time, acquires a yellowish tinge, and a strawy smell, from dissolving some of the extractive matter of the barley husks. The grain imbibes about one half its weight of water, and increases in size by about one fifth. By losing this extract, the husk becomes about one seventieth lighter in weight, and paler in color.

The duration of the steep depends, in some measure, upon the temperature of the air, and is shorter in summer than in winter. In general from 40 to 48 hours will be found sufficient for sound dry grain. Steeping has for its object to expand the farina of the barley with humidity, and thus prepare the seed for germination, in the same way as the moisture of the earth prepares for the growth of the radicle and plumula in seed sown in it. Too long continuance in the steep is injurious; because it prevents the germination at the proper time, and thereby exhausts a portion of the vegetative power: it causes also an abstraction of saccharine matter by the water. The maceration is known to be complete when the grain may be easily transfixed with a needle, and is swollen to its full size. The following is reckoned a good test:—If a barley-corn, when pressed between the thumb and fingers, continues entire in its husk, it is not sufficiently steeped; but if it sheds its flour upon the fingers, it is ready. When the substance exudes in the form of a milky juice, the steep has been too long continued, and the barley is spoiled for germination.

In warm weather it sometimes happens that the water becomes acescent before the grain is thoroughly swelled. This accident, which is manifest to the taste and smell, must be immediately obviated by drawing off the foul water through the tap at the bottom of the cistern, and replacing it with fresh cold water. It does no harm to renew it two or three times at one steep.

The *couch.*—The water being drawn off, and occasionally a fresh quantity passed through, to wash away any slimy matter which may have been generated in warm weather, the barley is now laid upon the couch floor of stone flags, in square heaps from 12 to 16 inches high, and left in that position for 24 hours. At this period, the bulk of the grain being the greatest, it may be gauged by the revenue officers if they think fit. The moisture now leaves the surface of the barley so completely, that it imparts no dampness to the hand. By degrees, however, it becomes warm; the temperature rising 10° above the atmosphere, while an agreeable fruity smell is evolved. At this time if the hand be thrust into the heap, it not only feels warm, but it gets bedewed with moisture. At this sweating stage, the germination begins; the fibrils of the radicle first sprout forth from the tip of every grain, and a white elevation appears, that soon

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separates into three or more radicles, which grow rapidly larger. About a day after this appearance, the plumula peeps forth at the same point, proceeding thence beneath the husk to the other end of the seed, in the form of a green leaflet.

The greatest heat of the couch is usually about 96 hours after the barley has been taken out of the steep. In consequence, the radicles tend to increase in length with very great rapidity, and must be checked by artificial means, which constitute the chief art of the maltster. He now begins to spread the barley thinner on the floor, and turns it over several times in the course of a day, bringing the portions of the interior into the exterior surface. The depth, which was originally 15 or 16 inches, is lowered a little at every turning over, till it be brought eventually down to three or four inches. Two turnings a day are generally required. At this period of spreading or flooring, the temperature in England is about 62°, and in Scotland 5 or 6 degrees lower.

About a day after the radicles appear, the rudiments of the stem, or of the plumula, sprout forth, called by the English maltsters the *acrospire*. It issues from the same end of the seed as the radicle, but turns round, and proceeds within the husk towards the other end, and would there come forth as a green leaf, were its progress not arrested. The malting, however, is complete before the acrospire becomes a leaf.

The barley couch absorbs oxygen and emits carbonic acid, just as animals do in breathing, but to a very limited extent; for the grain loses only three per cent. of its weight upon the malt floor, and a part of this loss is due to waste particles. As the acrospire creeps along the surface of the seed, the farina within undergoes a remarkable alteration. The gluten and mucilage disappear, in a great measure, the color becomes whiter, and the substance becomes so friable that it crumbles into meal between the fingers. This is the great purpose of malting, and it is known to be accomplished when the plumula or acrospire has approached the end of the seed. Now the further growth must be completely stopped. Fourteen days may be reckoned the usual duration of the germinating stage of the malting operations in England; but in Scotland, where the temperature of the couch is lower, eighteen days, or even twenty-one, are sometimes required. The shorter the period within the above limits, the more advantageous is the process to the maltster, as he can turn over his capital the sooner, and his malt is also somewhat the better. Bigg is more rapid in its germination than barley, and requires to be still more carefully watched. In dry weather it is sometimes necessary to water the barley upon the couch.

Occasionally the odor disengaged from the couch is offensive, resembling that of rotten apples. This is a bad prognostic, indicating either that the barley was of bad quality, or that the workmen, through careless shovelling, have crushed a number of the grains in turning them over. Hence when the weather causes too quick germination, it is better to check it by spreading the heap out thinner than by turning it too frequently over. On comparing different samples of barley, we shall find that the best develop the germ or acrospire quicker than the radicles, and thus occasion a greater production of the saccharine principle; this conversion advances along with the acrospire, and keeps pace with it, so that the portion of the seed to which it has not reached is still in its unaltered starchy state. It is never complete for any single barleycorn till the acrospire has come to the end opposite to that from which it sprung; hence one part of the corn may be sugary, while the other is still insipid. If the grain were allowed to vegetate beyond this term, the radicles being fully one third of an inch long, the future stem would become visibly green in the exterior; it would shoot forth rapidly, the interior of the grain would become milky, with a complete exhaustion of all its useful constituents, and nothing but the husk would remain.

In France, the brewers, who generally malt their barley themselves, seldom leave it on the couch more than 8 or 10 days, which, even taking into account the warmer climate of their country, is certainly too short a period, and hence they make inferior wort to the English brewer, from the same quantity of malt.

At the end of the germination, the radicles have become 1½ longer than the barley, and are contorted so that the corns hook into one another, but the acrospire is just beginning to push through. A moderate temperature of the air is best adapted to malting; therefore it cannot be carried on well during the heat of summer or the colds of winter. Malt-floors should be placed in substantial thick-walled buildings, without access of the sun, so that a uniform temperature of 59° or 60° may prevail inside. Some recommend them to be sunk a little under the surface of the ground, if the situation be dry.

During germination a remarkable change has taken place in the substance of the grain. The glutinous constituent has almost entirely disappeared, and is supposed to have passed into the matter of the radicles, while a portion of the starch is converted into sugar and mucilage. The change is similar to what starch undergoes when dissolved in water, and digested in a heat of about 160° F. along with a little gluten.

The thick paste becomes gradually liquid, transparent, and sweet tasted, and the solution contains now, sugar and gum, mixed with some unaltered starch. The gluten suffers a change at the same time, and becomes acescent, so that only a certain quantity of starch can be thus converted by a quantity of gluten. By the artificial growth upon the malt-floor, all the gluten and albumen present in barley is not decomposed, and only about one half of the starch is converted into sugar; the other half, by a continuance of the germination, would only go to the growth of the roots and stems of the plant; but it receives its nearly complete conversion into sugar without any notable waste of substance in the brewer's operation of mashing.

The *kiln-drying.*—When the malt has become perceptibly dry to the hand upon the floor, it is taken to the kiln, and dried hard with artificial heat, to stop all further growth, and enable it to be kept, without change, for future use, at any time. The malt-kiln, which is particularly described in the next page, is a round or a square chamber, covered with perforated plates of cast iron, whose area is heated by a stove or furnace, so that not merely the plates on which the malt is laid are warmed, but the air which passes up through the stratum of malt itself, with the effect of carrying off very rapidly the moisture from the grains. The layer of malt should be about 3 or 4 inches thick, and evenly spread, and its heat should be steadily kept at from the 90th to the 100th degree of Fahrenheit's scale, till the moisture be mostly exhaled from it. During this time the malt must be turned over at first frequently, and latterly every three or four hours. When it is nearly dry, its temperature should be raised to from 145° to 165° F., and it must be kept at this heat till it has assumed the desired shade of color, which is commonly a brownish-yellow or a yellowish-brown. The fire is now allowed to die out, and the malt is left on the plates till it has become completely cool; a result promoted by the stream of cool air, which now rises up through the bars of the grate; or the thoroughly dry browned malt may, by damping the fire, be taken hot from the plates, and cooled upon the floor of an adjoining apartment. The prepared malt must be kept in a dry loft, where it can be occasionally turned over till it is used. The period of kiln-drying should not be hurried. Many persons employ two days in this operation.

According to the color and the degree of drying, malt is distributed into three sorts; pale, yellow, and brown. The first is produced when the highest heat to which it has been subjected is from 90° to 100° F.; the amber yellow, when it has suffered a heat of 122°; and the brown when it has been treated as above described. The black malt used by the porter brewer to color his beer, has suffered a much higher heat, and is partially charred. The temperature of the kiln should, in all cases, be most gradually raised, and most equably maintained. If the heat be too great at the beginning, the husk gets hard dried, and hinders the evaporation of the water from the interior substance; and should the interior be dried by a stronger heat. the husk will probably split, and the farina become of a horny texture, very refractory in the mash-tun. In general, it is preferable to brown malt, rather by a long-continued moderate heat, than by a more violent heat of shorter duration, which is apt to carbonize a portion of the mucilaginous sugar, and to damage the article. In this way, the sweet is sometimes converted into a bitter principle.

During the kiln-drying, the roots and acrospire of the barley become brittle, and fall off; and are separated by a wire sieve whose meshes are too small to allow the malt itself to pass through.

A quantity of good barley, which weighs 100 pounds, being judiciously malted, will weigh, after drying and sifting, 80 pounds. Since the raw grain, dried by itself at the same temperature as the malt, would lose 12 per cent. of its weight in water, the malt process dissipates out of these remaining 88 pounds, only 8 pounds, or 8 per cent. of the raw barley. This loss consists of—

1½	per cent.	dissolved out in the steep water,
3	—	dissipated in the kiln,
3	—	by the falling of the fibrils,
½	—	of waste.

The bulk of good malt exceeds that of the barley from which it was made, by about 8 or 9 per cent.

The operation of kiln-drying is not confined to the mere expulsion of the moisture from the germinated seeds; but it serves to convert into sugar a portion of the starch which remained unchanged, and that in a twofold way; first, by the action of the gluten upon the fecula at an elevated temperature, as also by the species of roasting which the starch undergoes, and which renders it of a gummy nature. (See STARCH.) We shall have a proof of this explanation, if we dry one portion of the malt in a naturally dry atmosphere, and another in a moderately warm kiln; the former will yield less saccharine extract than the latter. Moreover, the kiln-dried malt has a peculiar, agreeable, and faintly burned taste, probably from a small portion of empyromatic oil formed in the husk, and which not only imparts its flavor to the beer, but also contributes to its preservation. It is therefore obvious, that the skilful preparation of the malt must have the greatest influence both on the quantity and quality of the worts to be made from it. If the germination be pushed too far, a part of the extractible matter is wasted; if it has not advanced far enough, the malt will be too raw, and too much of its substance will remain as an insoluble starch; if it is too highly kiln dried, a portion of its sugar will be caramelized, and become bitter; and if the sweating was imperfect or irregular, much of the barley may be rendered lumpy and useless. Good malt is distinguishable by the following characters:—

The grain is round and full, breaks freely between the teeth, and has a sweetish taste, an agreeable smell, and is full of a soft flour from end to end. It affords no unpleasant flavor on being chewed; it is not hard, so that when drawn along an oaken table across the fibres, it leaves a white streak, like chalk. It swims upon water, while unmalted barley sinks in it. Since the quality of the malt depends much on that of the barley, the same sort only should be used for one malting. New barley germinates quicker than old, which is more dried up; a couch of a mixture of the two would be irregular, and difficult to regulate.

Description of the malt-kiln.—*Figs.* 107,108,109,110, exhibit the construction of a well-contrived *malt-kiln*. *Fig.* 107, is the ground plan: *fig.* 108, is the vertical section; and *figs.* 109, and 110, a horizontal and vertical section in the line of the malt-plates. The same letters denote the same parts in each of the figures. A cast-iron cupola-shaped oven is

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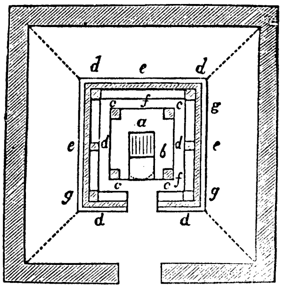

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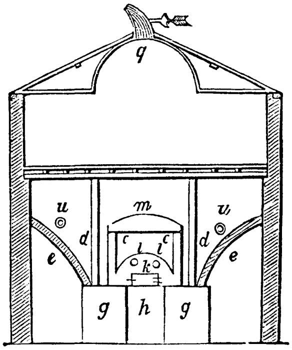

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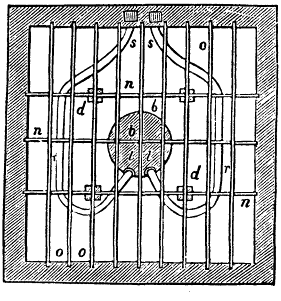

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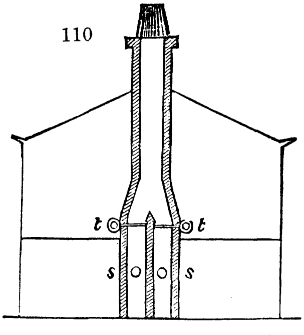


supported in the middle, upon a wall of brickwork four feet high; and beneath it, are the grate and its ash-pit. The smoke passes off through two equi-distant pipes into the chimney. The oven is surrounded with four pillars, on whose top a stone lintel is laid: *a* is the grate, 9 inches below the sole of the oven *b*; *c c c c* are the four nine-inch strong pillars of brickwork which bear the lintel *m*; *d d d d d d* are strong nine-inch pillars, which support the girder and joists upon which perforated plates repose; *e* denotes a vaulted arch on each of the four sides of the oven; *f* is the space between the kiln and the side arch, into which a workman may enter, to inspect and clean the kiln; *g g*, the walls on either side of the kiln, upon which the arches rest; *h*, the space for the ashes to fall, *k*, the fire-door of the kiln; *l l*, junction-pieces to connect the pipes *r r* with the kiln; the mode of attaching them is shown in *fig.* 109. These smoke-pipes lie about three feet under the iron plates, and at the same distance from the side walls: they are supported upon iron props, which are made fast to the arches. In *fig.* 108, *u* shows their section; at *s s*, *fig.* 109, they enter the chimney, which is provided with two register or damper plates, to regulate the draught through the pipes. These registers are represented by *t t*, *fig.* 110, which shows a perpendicular section of the chimney. *m*, *fig.* 108, is the lintel which causes the heated air to spread laterally instead of ascending in one mass in the middle, and prevents any combustible particles from falling upon the iron cupola. *n n* are the main girders of iron for the iron beams *o o*, upon which the perforated plates *p* lie; *q*, *fig.* 108, is the vapor pipe in the middle of the roof, which allows the steam of the drying malt to escape. The kiln may be heated either with coal or wood.

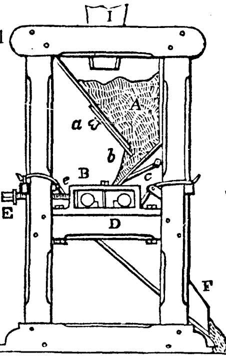
The size of this kiln is about 20 feet square; but it may be made proportionally either smaller or greater. The perforated floor should be large enough to receive the contents of one steep or couch.

The perforated plate might be conveniently heated by steam pipes, laid zig-zag, or in parallel lines under it; or a wire-gauze web might be stretched upon such pipes. The wooden joists of a common floor would answer perfectly to support this steam-range, and the heat of the pipes would cause an abundant circulation of air. For drying the pale malt of the ale brewer, this plan is particularly well adapted.

The kiln-dried malt is sometimes ground between stones in a common corn mill, like oatmeal; but it is more generally crushed between iron rollers, at least for the purposes of the London brewers.

The *crushing mill.*—The cylinder malt-mill is constructed as shown in *figs.* 111, 112. I is the sloping-trough, by which the malt is let down from its bin or floor to the hopper A of the mill, whence it is progressively shaken in between the rollers B D. The rollers are of iron, truly cylindrical, and their ends rest in bearers of hard brass, fitted into the side frames of iron. A screw E goes through the upright, and serves to force the bearer of the one roller towards that of the other, so as to bring them closer together when the crushing effect is to be increased. G is the square end of the axis, by which one of the rollers may be turned either by the hand or by power; the other derives its rotatory motion from a pair of equal-toothed wheels H, which are fitted to the other end of the axes of the rollers. *d* is a catch which works into the teeth of a ratchet-wheel on the end of one of the rollers (not shown in this view.) The lever *c* strikes the trough *b* at the bottom of the hopper, and gives it the shaking motion for discharging the malt between the rollers, from the slide sluice *a*. *e e*, *fig.* 111, are scraper-plates of sheet iron, the edges of which press by a weight against the surfaces of the rollers, and keep them clean.

111



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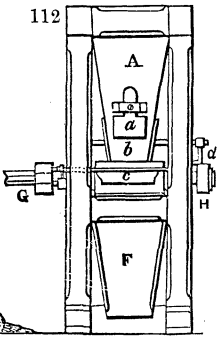

Instead of the cylinders, some employ a crushing mill of a conical-grooved form like a coffee-mill, upon a large scale. (*See the general plan, infrà.*)

The *mashing and boiling.*—Mashing is the operation by which the wort is extracted, or eliminated from the malt, and whereby a saccharo-mucilaginous extract is made from it. The malt should not in general be ground into a fine meal, for in that case it would be apt to form a cohesive paste with hot water, or to set, as it is called, and to be difficult to drain. In crushed malt, the husk remains nearly entire, and thus helps to keep the farinaceous particles open and porous to the action of the water. The bulk of the crushed malt is about one fifth greater than that of the whole, or one bushel of malt gives a bushel and a quarter of crushed malt. This is frequently allowed to lie a few days in a cool place, in order that it may attract moisture from the air, which it does very readily by its hygrometric power. Thus, the farinaceous substance which had been indurated in the kiln, becomes soft, spongy, and fit for the ensuing process of watery extraction.

Mashing has not for its object merely to dissolve the sugar and gum already present in the malt, but also to convert into a sweet mucilage the starch which had remained unchanged during the germination. We have already stated that starch, mixed with gluten, and digested for some time with hot water, becomes a species of sugar. This conversion takes place in the mash-tun. The malted barley contains not only a portion of gluten, but *diastase* more than sufficient to convert the starch contained in it, by this means, into sugar.

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The researches of Payen and Persoz show, that the mucilage formed by the reaction of malt upon starch, may either be converted into sugar, or be made into permanent gum, according to the temperature of the water in which the materials are digested. We take of pale barley malt, ground fine, from 6 to 10 parts, and 100 parts of starch; we heat, by means of a water-bath, 400 parts of water in a copper, to about 80° F.; we then stir in the malt, and increase the heat to 140° F., when we add the starch, and stir well together. We next raise the temperature to 158°, and endeavor to maintain it constantly at that point, or at least to keep it within the limits of 167° on the one side, and 158° on the other. At the end of 20 or 30 minutes, the original milky and pasty solution becomes thinner, and soon after as fluid nearly as water. This is the moment in which the starch is converted into gum, or into that substance which the French chemists call *dextrine*, from its power of polarizing light to the right hand, whereas common gum does it to the left. If this merely mucilaginous solution, which seems to be a mixture of gum with a little liquid starch and sugar, be suitably evaporated, it may serve for various purposes in the arts to which gum is applied, but with this view, it must be quickly raised to the boiling point, to prevent the farther operation of the malt upon it. If we wish, on the contrary, however, to promote the saccharine fermentation, for the formation of beer, we must maintain the temperature at between 158° and 167° for three or four hours, when the greatest part of the gum will have passed into sugar, and by evaporation of the liquid at the same temperature, a starch sirup may be obtained like that procured by the action of sulphuric acid upon starch. The substance, which operates in the formation of sugar, or is the peculiar ferment of the sugar fermentation, may be considered as a residuum of the gluten or vegetable albumen in the germinating grain: it is reckoned by Payen and Persoz, a new proximate principle called *diastase*, which is formed during malting, in the grains of barley, oats, and wheat, and may be separated in a pure state, if we moisten the malt flour for a few minutes in cold water, press it out strongly, filter the solution, and heat the clear liquid in a water bath, to the temperature of 158°. The greater part of that albuminous azotized substance is thus coagulated, and is to be separated by a fresh filtration; after which, the clear liquid is to be treated with alcohol, when a flocky precipitate appears, which is *diastase*. To purify it still further, especially from the azotized matter, we should dissolve it in water, and precipitate again with alcohol. When dried at a low temperature, it appears as a solid white substance, which contains no azote; is insoluble in alcohol, but dissolves in water and proof spirit. Its solution is neutral and tasteless; when left to itself, it changes with greater or less rapidity according to the temperature, and becomes sour at a temperature of from 149° to 167°. It has the property of converting starch into gum (dextrine) and sugar, and indeed, when sufficiently pure, with such energy that one part of it disposes 2000 parts of dry starch to that change, but it operates the quicker the greater its quantity. Whenever the solution of diastase with starch or with dextrine is heated to the boiling point, it loses the sugar-fermenting property. One hundred parts of well-malted starch appear to contain about one part of this substance.

We can now understand the theory of malting, and the limits between which the temperature of the liquor ought to be maintained in this operation; namely, the range between 157° and 160° F.' It has been ascertained as a principle in mashing, that the best and soundest extract of the malt is to be obtained, first of all, by beginning to work with water at the lowest of these heats, and to conclude the mash with water at the highest. Secondly, not to operate the extraction at once with the whole of the water that is to be employed; but with separate portions and by degrees. The first portion is added with the view of penetrating equally the crushed malt, and of extracting the already formed sugar; the next for effecting the sugar fermentation by the action of the diastase. By this means, also, the starch is not allowed to run into a cohesive paste, and the extract is more easily drained from the poorer mass, and comes off in the form of a nearly limpid wort. The thicker, moreover, or the less diluted the mash is, so much the easier is the wort fined in the boiler or copper by the coagulation of the albuminous matter: these principles illustrate, in every condition, the true mode of conducting the mashing process; but different kinds of malt require a different treatment. Pale and slightly kilned malt requires a somewhat lower heat than malt highly kilned, because the former has more undecomposed starch, and is more ready to become pasty. The former also, for the same reason, needs a more leisurely infusion than the latter, for its conversion into mucilaginous sugar. The more sugar the malt contains, the more is its saccharine fermentation accelerated by the action of the diastase. What has been here said of pale malt, is still more applicable to the case of a mixture of raw grain with malt, for it requires still gentler heats, and more cautious treatment.

III. The mash-tun is a large circular tub with a double bottom; the uppermost of which is called a false bottom, and is pierced with many holes. There is a space of about 2 or 3 inches between the two, into which the stopcocks enter, for letting in the water and drawing off the wort. The holes of the false bottom should be burned, and not bored, to prevent the chance of their filling up by the swelling of the wood, which would obstruct the drainage: the holes should be conical, and largest below, being about $\frac{3}{8}$ of an inch there, and $\frac{1}{8}$ at the upper surface. The perforated bottom must be fitted truly at the sides of the mash-tun, so that no grains may pass through. The mashed liquor is let off into a large back, from which it is pumped into the wort coppers. The mash-tun is provided with a peculiar rotatory apparatus for agitating the crushed grains and water together, which we shall presently describe. The size of the wort copper is proportional to the amount of the brewing, and it must, in general, be at least so large as to operate upon the whole quantity of wort made from one mashing; that is, for every quarter of malt mashed, the copper should contain 140 gallons. The mash-tun ought to be at least a third larger, and of a conical form, somewhat wider below than above. The quantity of water to be employed for mashing, or the extraction of the wort, depends upon the greater or less strength to be given to the beer. The seeds of the crushed malt, after the wort is drawn off, retain still about 32 gallons of water for every quarter of malt. In the boiling, and evaporation from the coolers, 40 gallons of water are dissipated from one quarter of malt; constituting 72 gallons in all. If 13 quarters of barley be taken to make 1500 gallons of beer, 2400 gallons of water must therefore be required for the mashing. This example will give an idea of the proportions for an ordinary quality of beer.

When the mash is to begin, the copper must be filled with water, and heated. As soon as the water has attained the heat of 145° in summer, or 167° in winter, 600 gallons of it are to be run off into the mash-tun, and the 13 quarters of crushed malt are to be gradually thrown in and well intermixed by proper agitation, so that it may be uniformly moistened, and no lumps may remain. After continuing the agitation in this way for one half or three quarters of an hour, the water in the copper will have approached to its boiling point, when 450 gallons at the temperature of about 200° are to be run into the mash-tun, and the agitation is to be renewed till the whole assumes an equally fluid state: the tun is now to be well covered for the preservation of its heat, and to be allowed to remain at rest for an hour, or an hour and a half. The mean temperature of this mash may be reckoned at about 145°. The time which is necessary for the transmuting heat of the remaining starch into sugar depends on the quality of the malt. Brown malt requires less time than pale malt, and still less than a mixture with raw grain, as already explained. After the mash has rested the proper time, the tap of the tun is opened, and the clear wort is to be drawn out into the under back. If the wort that first flows is turbid, it must be returned into the tun, till it runs clear. The amount of this first wort may be about 675 gallons. Seven hundred and fifty gallons of water, at the temperature of 200°, are now to be introduced up through the drained malt, into the tun, and the mixture is to be agitated till it becomes uniform, as before. The mash-tun is then to be covered, and allowed to remain at rest for an hour. The temperature of this mash is from 167° to 174°. While the second mash is making, the worts of the first are to be pumped into the wort copper, and set a-boiling as speedily as possible. The wort of the second mash is to be drawn off at the proper time, and added to the copper as fast as it will receive it, without causing the ebullition to stop.

A third quantity of water amounting to 600 gallons, at 200°, is to be introduced into the mash-tun, and after half an hour is to be drawn off, and either pumped into the wort copper, or reserved for mashing fresh malt, as the brewer may think fit.

The quantity of extract, per barrel weight, which a quarter of malt yields to wort, amounts to about 84 lbs. The wort of the first extract is the strongest; the second contains, commonly, one half the extract of the first; and the third, one half of the second; according to circumstances.

To measure the degrees of concentration of the worts drawn off from the tun, a particular form of hydrometer, called a saccharometer, is employed, which indicates the number of pounds weight of liquid contained in a barrel of 36 gallons imperial measure. Now, as the barrel of water weighs 360 lbs., the indication of the instrument, when placed in any wort, shows by how many pounds a barrel of that wort is heavier than a barrel of water; thus, if the instrument sinks with its poise till the mark 10 is upon a line with the surface of the liquid, it indicates that a barrel of that wort weighs ten pounds more than a barrel of water. See SACCHAROMETER.

Or, supposing the barrel of wort weighs 396 lbs., to convert that number into specific gravity, we have the following simple rule:—

$$360 : 396 :: 100 : 1{\cdot}100;$$

at which density, by my experiments, the wort contains 25 per cent. of solid extract.

Having been employed to make experiments on the density of worts, and the fermentative changes which they undergo, for the information of a committee of the House of Commons, which sat in July and August, 1830, I shall here introduce a short abstract of that part of my evidence which bears upon the present subject.

My first object was to clear up the difficulties which, to common apprehension, hung over the matter, from the difference in the scales of the saccharometers in use among the brewers and distillers of England and Scotland. I found that one quarter of good malt would yield to the porter-brewer a barrel Imperial measure of wort, at the concentrated specific gravity of 1·234. Now, if the decimal part of this number be multiplied by 360, being the number of pounds weight of water in the barrel, the product will denote the excess in pounds, of the weight of a barrel of such concentrated wort, over that of a barrel of water; and that product is, in the present case, 84·24 pounds.

Mr. Martineau, jun., of the house of Messrs. Whitbread and Company, and a gentleman connected with another great London brewery, had the kindness to inform me that their average product from a quarter of malt was a barrel of 84 lbs. gravity. It is obvious, therefore, that by taking the mean operation of two such great establishments, I must have arrived very nearly at the truth.

It ought to be remarked that such a high density of wort as 1·234 is not the result of any direct experiment in the brewery, for infusion of malt is never drawn off so strong; that density is deduced by computation from the quantity and quality of several successive infusions; thus, supposing a first infusion of the quarter of malt to yield a barrel of specific gravity 1·112, a second to yield a barrel at 1·091, and a third a barrel at 1·031, we shall have three barrels at the mean of these three numbers, or one barrel at their sum, equal to 1·234.

I may here observe that the arithmetical mean or sum is not the true mean or sum of the two specific gravities; but this difference is either not known or disregarded by the brewers. At low densities this difference is inconsiderable, but at high densities it would lead to serious errors. At specific gravity 1·231, wort or sirup contains one half of its weight of solid pure saccharum, and at 1·1045 it contains one fourth of its weight; but the brewer's rule, when here applied, gives for the mean specific gravity $1{\cdot}1155 = \frac{1{\cdot}231 + 1{\cdot}000.}{2}$ The contents in solid saccharine matter at that density are however 27¼ per cent., showing the rule to be 2¼ lbs. wrong in excess on 100 lbs., or 9 lbs. per barrel.

The specific gravity of the solid dry extract of malt wort is 1·264; it was taken in oil of turpentine, and the result reduced to distilled water as unity. Its specific volume is 0·7911, that is, 10 lbs. of it will occupy the volume of 7·911 lbs. of water. The mean specific gravity, by computation of a solution of that extract in its own weight of water, is 1·1166; but by experiment, the specific gravity of that solution is 1·216, showing considerable condensation of volume in the act of combination with water.

The following Table shows the relation between the specific gravities of solutions of malt extract, and the per-centage of solid extract they contain:

Extr Malt.		Water.	Malt Extract in 100.	Sugar in 100.	Specific gravity.
600	+	600	50·00	47·00	1·2160
600	+	900	40·0	37·00	1·1670
600	+	1200	33·3	31·50	1·1350
600	+	1500	28·57	26·75	1·1130
600	+	1800	25·00	24·00	1·1000

The extract of malt was evaporated to dryness, at a temperature of about 250° F., without the slightest injury to its quality, or any empyreumatic smell. Bate's tables have been constructed on solutions of sugar, and not with solutions of extract of malt, or they agree sufficiently well with the former, but differ materially from the latter. Allan's tables give the amount of a certain form of solid saccharine matter extracted from malt and dried at 175° F., in correspondence to the specific gravity of the solution; but I have found it impossible to make a solid extract from infusions of malt, except at much higher temperatures than 175° F. Indeed, the numbers on Allan's saccharometer scale clearly show that his extract was by no means dry: thus, at 1·100 of gravity he assigns 29·669 per cent. of solid saccharine matter; whereas there is at that density of solid extract only 25 per cent. Again, at 1·135, Allan gives 40 parts per cent. of solid extract, whereas there are only 33⅓ present.

By the triple mashing operations above described, the malt is so much exhausted that it can yield no further extract useful for strong beer or porter. A weaker wort might no doubt still be drawn off for small beer, or for contributing a little to the strength of the next mashing of fresh malt. But this I believe is seldom practised by respectable brewers, as it impoverishes the grains which they dispose of for feeding cattle.

The wort should be transferred into the copper, and made to boil as soon as possible, for if it remains long in the under-back it is apt to become acescent. The steam moreover raised from it in the act of boiling serves to screen it from the oxygenating or acidifying influence of the atmosphere. Until it begins to boil, the air should be excluded by some kind of a cover.

Sometimes the first wort is brewed by itself into strong ale, the second by itself into an intermediate quality; and the third into small beer; but this practice is not much followed in this country.

We shall now treat of the boiling in of the hops. The wort drawn from the mash-tun, whenever it is pumped into the copper, must receive its allowance of hops. Besides evaporating off a portion of the water, and thereby concentrating the wort, boiling has a twofold object. In the first place, it coagulates the albuminous matter, partly by the heat, and partly by the principles in the hops, and thereby causes a general clarification of the whole mass, with the effect of separating the muddy matters in a flocculent form. Secondly, during the ebullition, the residuary starch and hordeine of the malt are converted into a limpid sweetish mucilage, the *dextrine* above described; while some of the glutinous stringy matter is rendered insoluble by the tannin principle of the hops, which favors still further the clearing of the wort. By both operations the keeping quality of the beer is improved. This boil must be continued during several hours; a longer time for the stronger, and a shorter for the weaker beers. There is usually one seventh or one sixth part of the water dissipated in the boiling copper. This process is known to have continued a sufficient time, if the separation of the albuminous flocks is distinct, and if these are found, by means of a proof gauge suddenly dipped to the bottom, to be collected there, while the supernatant liquor has become limpid. Two or three hours' boil is deemed long enough in many well-conducted breweries; but in some of those in Belgium, the boiling is continued from 10 to 15 hours, a period certainly detrimental to the aroma derived from the hop.

Many prefer adding the hops when the wort has just come to the boiling point. Their effect is to repress the further progress of fermentation, and especially the passage into the acetous stage, which would otherwise inevitably ensue in a few days. In this respect, no other vegetable production hitherto discovered can be a substitute for the hop. The odorant principle is not so readily volatilized as would at first be imagined; for when hop is mixed with strong beer wort and boiled for many hours, it can still impart a very considerable degree of its flavor to weaker beer. By mere infusion in hot beer or water, without boiling, the hop loses very little of its soluble principles. The tannin of the hop combines, as we have said, with the vegetable albumen of the barley, and helps to clarify the liquor. Should there be a deficiency of albumen and gluten, in consequence of the mashing having been done at such a heat as to have coagulated them beforehand, the defect may be remedied by the addition of a little gelatine to the wort copper, either in the form of calf's foot, or of a little isinglass. If the hops be boiled in the wort for a longer period than 5 or 6 hours, they lose a portion of their fine flavor; but if their natural flavor be rank, a little extra boiling improves it. Many brewers throw the hops in upon the surface of the boiling wort, and allow them to swim there for some time, that the steam may penetrate them, and open their pores for a complete solution of their principles when they are pushed down into the liquor. It is proper to add the hops in considerable masses, because, in tearing them asunder, some of the lupuline powder is apt to be lost.

The quantity of hop to be added to the wort varies according to the strength of the beer, the length of time it is to be kept, or the heat of the climate where it is intended to be sent. For strong beer, 4½ lbs. of hops are required to a quarter of malt, when it is to be highly aromatic and remarkably clear. For the stronger kinds of ale and porter, the rule, in England, is to take a pound of hops for every bushel of malt, or 8 lbs. to a quarter. Common beer has seldom more than a quarter of a pound of hops to the bushel of malt.

It has been attempted to form an extract of hops by boiling in covered vessels, so as not to lose the oil, and to add this instead of the hop itself to the beer. On the great scale this method has no practical advantage, because the extraction of the hop is perfectly accomplished during the necessary boiling of the wort, and because the hop operates very beneficially, as we have explained, in clarifying the beer. Such an extract, moreover, could be easily adulterated.

Of the Coolers.—The contents of the copper are run into what is called the hop-back, on the upper part of which is fixed a drainer, to keep back the hops. The pump is placed in the hop-back, for the purpose of raising the wort to the coolers, usually placed in an airy situation upon the top of the brewery. Two coolers are indispensable when we make two kinds of beer from the same brewing, and even in single brewings, called *gyles*, if small beer is to be made. One of these coolers ought to be placed above the level of the other. As it is of great consequence to cool the worts down to the fermenting pitch as fast as possible, various contrivances have been made for effecting this purpose. The common cooler is a square wooden cistern, about 6 inches deep, and of such an extent of surface that the whole of one boil may only occupy 2 inches, or thereabouts, of depth in it. For a quantity of wort equal to about 1500 gallons its area should be at least 54 feet long and 20 feet wide. The seams of the cooler must be made perfectly water-tight and smooth, so that no liquor may lodge in them when they are emptied. The utmost cleanliness is required, and an occasional sweetening with lime-water.

The hot wort reaches the cooler at a temperature of from 200° to 208°, according to the power of the pump. Here it should be cooled to the proper temperature for the fermenting tun, which may vary from 54° to 64°, according to circumstances. The refrigeration is accomplished by the evaporation of a portion of the liquor: it is more rapid in proportion to the extent of the surface, to the low temperature, and the dryness of the atmosphere surrounding the cooler. The renewal of a body of cool dry air by the agency of a fan, may be employed with great advantage. The cooler itself must be so placed that its surface shall be freely exposed to the prevailing wind of the district, and be as free as possible from the eddy of surrounding buildings. It is thought by many that the agitation of the wort during its cooling is hurtful. Were the roof made moveable, so that the wort could be readily exposed, in a clear night, to the aspect of the sky, it would cool rapidly by evaporation, on the principles explained by Dr. Wells, in his "Essay on Dew."

When the cooling is effected by evaporation alone, the temperature falls very slowly, even in cold air, if it be loaded with moisture. But when the air is dry, the evaporation is vigorous, and the moisture exhaled does not remain incumbent on the liquor, as in damp weather, but is diffused widely in space. Hence we can understand how wort cools so rapidly in the spring and autumn, when the air is generally dry, and even more quickly than in winter, when the air is cooler, but loaded with moisture. In fact, the cooling process goes on better when the atmosphere is from 50° to 55°, than when it falls to the freezing point, because in this case, if the air be still, the vapors generated remain on the surface of the liquor, and prevent further evaporation. In summer the cooling can take place only during the night.

In consequence of the evaporation during this cooling process, the bulk of the worts is considerably reduced; thus, if the temperature at the beginning was 208°, and if it be at the end 64°, the quantity of water necessary to be evaporated to produce this refrigeration would be nearly $\frac{1}{8}$ of the whole, putting radiation and conduction of heat out of the question. The effect of this will be a proportional concentration of the beer.

The period of refrigeration in a well-constructed cooler, amounts to 6 or 7 hours in favorable weather, but to 12 or 15 in other circumstances. The quality of the beer is much improved by shortening this period; because, in consequence of the great surface which the wort exposes to the air, it readily absorbs oxgyen, and passes into the acetous fermentation with the production of various mouldy spots; an evil to which ill-hopped beer is particularly liable. Various schemes have been contrived to cool wort, by transmitting it through the convolutions of a pipe immersed in cold water. The best plan is to expose the hot wort for some hours freely to the atmosphere and the cooler, when the loss of heat is most rapid by evaporation and other means, and when the temperature falls to 100°, or thereby, to transmit the liquor through a zig-zag pipe, laid almost horizontally in a trough of cold water. The various methods described under *Refrigerator* are more complex, but they may be practised in many situations with considerable advantage.

Whilst the wort reposes in the cooler, it lets fall a slight sediment, which consists partly of fine flocks of coagulated albumen combined with tannin, and partly of starch, which had been dissolved at the high temperature, and separates at the lower. The wort should be perfectly limpid, for a muddy liquor never produces transparent beer. Such beer contains, besides mucilaginous sugar and gum, usually some starch, which even remains after the fermentation, and hinders its clarifying, and gives it a tendency to sour. The wort contains more starch the hotter it has been mashed, the less hops have been added, and the shorter time it has been boiled. The presence of starch in the wort may be made manifest by adding a little solution of iodine in alcohol to it, when it will become immediately blue. We thus see that the tranquil cooling of wort in a proper vessel has an advantage over cooling it rapidly by a refrigeratory apparatus. When the wort is sufficiently cool, it is let down into the fermenting tun. In this transfer the cooling might be carried several degrees lower, were the wort made to pass down through a tube enclosed in another tube, along which a stream of cold water is flowing in the opposite direction, as we have described in the sequel of Acetic acid. These fermenting tuns are commonly called *gyle-tuns*, or working tuns, and are either square or circular, the latter being preferable on many accounts.

IV. *Of the Fermentation.*—In the great London breweries, the size of these fermenting tuns is such that they contain from 1200 to 1500 barrels. The quantity of wort introduced at a time must, however, be considerably less than the capacity of the vessel, to allow room for the head of yeast which rises during the process; if the vessel be cylindrical, this head is proportional to the depth of the worts. In certain kinds of fermentation, it may rise to a third of that depth. In general, the fermentation proceeds more uniformly and constantly in large masses, because they are little influenced by vicissitudes of temperature; smaller vessels, on the other hand, are more easily handled. The *general* view of fermentation will be found under that title; I shall here make a few remarks on what is peculiar to beer. During the fermentation of wort, a portion of its saccharine matter is converted into alcohol, and wort thus changed is beer. It is necessary that this conversion of the sugar be only partial, for beer which contains no undecomposed sugar would soon turn sour, and even in the casks its alcohol undergoes a slow fermentation into vinegar. The amount of this excess of sugar is greater in proportion to the strength of the wort, since a certain quantity of alcohol, already formed, prevents the operation of the ferment on the remaining wort. Temperature has the greatest influence upon the fermentation of wort. A temperature of from 55° to 60° of the liquor, when that of the atmosphere is 55°, is most advantageous for the commencement. The warmth of the wort as it comes into the gyle-tun must be modified by that of the air in the apartment. In winter, when this apartment is cold, the wort should not be cooled under 64° or 60°, as in that case the fermentation would be tedious or interrupted, and the wort liable to spoil or become sour. In summer, when the temperature of the place rises to above 75°, the wort should be cooled, if possible, down to 55°, for which purpose it should be let in by the system of double pipes, above mentioned. The higher the temperature of the wort, the sooner will the fermentation begin and end, and the less is it in our power to regulate its progress. The expert brewer must steer a middle course between these two extremes, which threaten to destroy his labors. In some breweries a convoluted pipe is made to traverse or go round the sides of the gyle-tun, through which warm water is allowed to flow in winter, and cold in summer, so as to modify the temperature of the mass to the proper fermenting pitch. If there be no contrivance of this kind, the apartment may be cooled in summer, by suspending wet canvass opposite the windows in warm weather, and kindling a small stove within it in cold.

When the wort is discharged into the gyle-tun, it must receive its dose of yeast, which has been previously mixed with a quantity of the wort, and left in a warm place till it has begun to ferment. This mixture, called *lobb*, is then to be put into the tun, and stirred well through the mass. The yeast should be taken from similar beer. Its quantity must depend upon the temperature, strength, and quantity of the wort. In general, one gallon of yeast is sufficient to set 100 gallons of wort in complete fermentation. An excess of yeast is to be avoided, lest the fermentation should be too violent, and be finished in less than the proper period of 6 or 8 days. More yeast is required in winter than in summer; for, at a temperature of 50°, a double quantity may be used to that at 68°.

Six or eight hours after adding the yeast, the tun being meanwhile covered, the fermentation becomes active: a white milky-looking froth appears, first on the middle, and spreads gradually over the whole surface; but continues highest in the middle, forming a frothy elevation, the height of which increases with the progress of the fermentation, and whose color gradually changes to a bright brown, the result, apparently, of the oxydation of the extractive contained in this yeasty top. This covering screens the wort from the contact of the atmospherical air. During this time, there is a perpetual disengagement of carbonic acid gas, which is proportional to the quantity of sugar converted into alcohol. The warmth of the fermenting liquid increases at the same time, and is at a maximum when the fermentation has come to its highest point. This increase of temperature amounts to from 9° to 14° or upwards, and is the greater the more rapid the fermentation. But in general, the fermentation is not allowed to proceed so far in the gyle-tun, for after it is advanced a little way, the beer is *cleansed*, that is, drawn off into other vessels, which are large barrels set on end, with large openings in their top, furnished with a sloping tray for discharging an excess of yeast into the wooden trough, in which the *stillions* stand. These *stillions* are placed in communication with a store-tub, which keeps them always full, by hydrostatic pressure, so that the head of yeast may spontaneously flow over, and keep the body of liquor in the cask clean. This apparatus will be explained in describing the brewery plant. See the *figures, infrà.*

It must be observed, that the quantity of yeast, and the heat of fermentation, differ for every different quality of beer. For mild ale, when the fermentation has reached 75° its first flavor begins; at 80° the flavor increases; at 85° it approaches the high flavor; at 90° it is high; but it may be carried to 100° and upwards, for particular purposes. A wort of 30lbs. per barrel (sp. gr. 1·088), ought to increase about 15°, so that in order to arrive at 80°, it should be set at 65°. The quantity of yeast for such an ale should be from 2 to 3 lbs. per barrel. The higher the heat, the less yeast is necessary. If the heat of the fermentation should at any time fall, it must be raised by a supply of fresh yeast, well stirred in; but this practice is not advisable in general, because rousing the worts in the gyle-tun is apt to communicate a rank flavor of yeast to the ale. It is the practice of many experienced brewers to look every 2 hours into the gyle-tun, chiefly with the view of observing the progress of the heat, which is low at first, but afterwards often increases half a degree per hour, and subsequently declines, as the fermentation approaches its conclusion, till at length the heat becomes uniform, or sometimes decreases, before the fermentation is finished, especially where the quantity operated upon is small.

Some brewers recommend, when the fermentation is carried to its utmost period, to add about 7 lbs. of wheat or bean flour to a gyle-tun of 25 or 30 barrels, at the time of *cleansing*, so as to quicken the discharge of the yeast, by disengagement of more carbonic acid. The flour should be whisked up in a pail, with some of the beer, till the lumps are broken, and then poured in. By early cleansing, the yeast is preserved longer in a state proper for a perfect fermentation than by a contrary practice.

For old ale, which is to be long kept, the heat of the fermentation should not exceed 75°, but a longer time is required to complete the fermentation and ensure the future good flavor of the ale.

For porter, the general practice is, to use from 4 to 4½ lbs. of hops per barrel for keeping; though what is termed mild or mixing porter, has not more than 3 or 3½ lbs. The heat of fermentation must not exceed 70°, and begin about 60°. If the heat tend to increase much above that pitch in the gyle-tun, the porter should be *cleansed*, by means of the *stillions*. At this period of the fermentation, care should be taken that the sweetness of the malt be removed, for which purpose more yeast may be used than with any other beer of the same strength. The quantity is from 3 to 4 lbs. per barrel, rousing the wort in the gyle-tun every 2 hours in the day-time.

When the plan of *cleansing* casks is not employed, the yeast is removed from the surface of the fermenting tun by a skimmer, and the clear beer beneath is then drawn off into the ripening tuns, called *store-vats*, in which it is mixed up with different brewings, to suit the taste of the customers. This transfer must take place whenever the extrication of carbonic acid has nearly ceased; lest the alcohol formed should dissolve some of the floating yeast, acquire thereby a disagreeable taste, and pass partially into the acetous state.

In this process, during the formation of vinous spirit at the expense of the sugar, the albumen and gluten diffused through the beer, being acted upon by the alcohol, become insoluble; one portion of them is buoyed to the top with the carbonic acid gas, to form the frothy yeast; and another portion falls to form the bottom barm. The former consists of the same materials as the wort, with a large proportion of gluten, which forms its active constituent; the latter is a peculiar deposite, consisting of the same gluten mixed with the various dense impurities of the wort, and may be also used as a ferment, but is cruder than the floating yeast. The amount of yeast is proportional to the activity of the fermentation, or extrication of carbonic acid gas, as also to the heat of the mashing process, and the quantity of starch or flour unaltered by germination. Pale malt affords, usually, more yeast than malt highly kilned. When the yeast becomes excessive, from too violent fermentation, it should be skimmed off from time to time, which will tend to cool the liquor and moderate the intestine changes.

After the beer is let down into the close store-tuns in the cellar, an obscure fermentation goes on, for a considerable period, in its body, which increases its spirituous strength, and keeps up in it a constant impregnation of carbonic acid gas, so as to render it lively and agreeable to the taste, when it is casked off for sale. It would appear that beer is never stationary in quality, while it is contained in the tuns; for the moment when it ceases to improve by the decomposition of its residuary sugar, it begins to degenerate into vinegar. This result may be produced either by the exhaustion of the saccharine, or by the fermentative matter. The store cellar should therefore be under ground, free from alternations of temperature, vibrations of carriages, and as cool as possible. In the great London breweries the fermentation is rendered very complete in the cleansing butts; so that a slow and steady ripening is ensured in the great store-tuns. The gyle-tuns are too capacious to permit the fermentation to be finished, with either safety or sufficient despatch in them.

V. Of ripening different kinds of Beer.—The varieties of beer depend either upon the difference of their materials, or from a different management of the brewing processes.

With regard to the materials, beers differ in the proportion of their malt, hops, and water; and in the different kinds of malt or other grain. To the class of table or small beers, all those sorts may be referred whose specific gravity does not exceed 1·025, which contain about 5 per cent. of malt extract, or nearly 18 pounds per barrel. Beers of middling strength may be reckoned those between the density of 1·025 and 1·040; which contain at the average 7 per cent. or 25 pounds per barrel. The latter may be made with 400 quarters of malt to 1500 barrels of beer. Stronger beers have a specific gravity of from 1·050 to 1·080, and take from 45 to 75 quarters of malt to the same quantity of beer. The strongest beer found in the market is some of the English and Scotch ales, for which from 18 to 27 quarters of malt are taken for 150C gallons of beer. Good porter requires from 16 to 18 quarters for that quantity. Beers are sometimes made with the addition of other farinaceous matter to the malt; but when the latter constitutes the main portion of the grain, the malting of the other kinds of corn becomes unnecessary, for the diastase of the barley-malt changes the starch into sugar during the mashing operation. Even with entirely raw grain, beer is made in some parts of the Continent, the brewers trusting the conversion of the starch into sugar to the action of the gluten alone, at a low mashing temperature, on the principle of Saussure's and Kirchoff's researches.

The color of the beer depends upon the color of the malt, and the duration of the boil in the copper. The pale ale is made, as we have stated, from steam or sun-dried malt, and the young shoots of the hop; the deep yellow ale from a mixture of pale yellow and brown malt; and the dark brown beer from well-kilned and partly carbonized malt, mixed with a good deal of the pale, to give body. The longer and more strongly heated the malt has been in the kiln, the less weight of extract, *cœteris paribus*, does it afford. In making the fine mild ales, high temperatures ought to be avoided, and the yeast ought to be skimmed off, or allowed to flow very readily from its top, by means of the cleansing butt system, so that little ferment being left in it to decompose the rest of the sugar, the sweetness may remain unimpaired. With regard to porter, in certain breweries, each of the three kinds of malt employed for it is separately mashed, after which the first and the half of the second wort is boiled along with the whole of the hops, and thence cooled and set to ferment in the gyle-tun. The third drawn wort, with the remaining half of the second, is then boiled with the same hops, saved by the drainer, and, after cooling, added to the former in the gyle-tun, when the two must be well roused together.

It is obvious, from the preceding development of principles, that all amylaceous and saccharine materials, such as potatoes, beans, turnips, as well as cane and starch sirup, molasses, &c., may be used in brewing beer. When, however, a superior quality of brown beer is desired, malted barley is indispensable, and even with these substitutes a mixture of it is most advantageous. The washed roots of the common carrot, of the red and yellow beet, or of the potato, must be first boiled in water, and then mashed into a pulp. This pulp must be mixed with water in the copper, along with wheaten or oat meal, and the proper quantity of hops, then boiled during 8 or 9 hours. This wort is to be cooled in the usual way, and fermented, with the addition of yeast. A much better process is that now practised, on a considerable scale, at Strasbourg, in making the ale, for which that city is celebrated. The mashed potatoes are mixed with from a twentieth to a tenth of their weight of finely ground barley malt, and some water. The mixture is exposed, in a water-bath, to a heat of 160° F. for four hours, whereby it passes into a saccharine state, and may then be boiled with hops, cooled, and properly fermented into good beer.

Maize, or Indian corn, has also been employed to make beer; but its malting is somewhat difficult on account of the rapidity and vigor with which its radicals and plumula sprout forth. The proper mode of causing it to germinate is to cover it, a few inches deep, with common soil, in a garden or field, and to leave it there till the bed is covered with green shoots of the plant. The corn must be then lifted, washed, and exposed to the kiln.

The Difference of the Fermentation.—The greater or less rapidity with which the worts are made to ferment has a remarkable influence upon the quality of the beer, especially in reference to its fitness for keeping. The wort is a mucilaginous solution in which the yeasty principles, eliminated by the fermentation, will, if favored by regular and slow intestine movements, completely rise to the surface, or sink to the bottom, so as to leave the body fine. But, when the action is too violent, these barmy glutinous matters get comminuted and dispersed through the liquor, and can never afterwards be thoroughly separated. A portion of the same feculent matter becomes, moreover, permanently dissolved, during this furious commotion, by the alcohol that is generated. Thus the beer loses not merely its agreeable flavor and limpidity, but is apt to spoil from the slightest causes. The slower, more regularly progressive, and less interrupted, therefore, the fermentation is, so much better will the product be.

Beer, in its perfect condition, is an excellent and healthful beverage, combining, in some measure, the virtues of water, of wine, and of food, as it quenches thirst, stimulates, cheers, and strengthens. The vinous portion of it is the alcohol, proceeding from the fermentation of the malt sugar. Its amount, in common strong ale or beer, is about 4 per cent., or four measures of spirits, specific gravity 0·825 in 100 measures of the liquor. The best brown stout porter contains 6 per cent., the strongest ale even 8 per cent.; but common beer only one. The nutritive part of the beer is the undecomposed gum-sugar, and the starch-gum, not changed into sugar. Its quantity is very variable, according to the original starch of the wort, the length of the fermentation, and the age of the beer

The main feature of good beer is fine color and transparency; the production of which is an object of great interest to the brewer. Attempts to clarify it in the cask seldom fail to do it harm. The only thing that can be used with advantage for *fining* foul or muddy beer, is isinglass. For porter, as commonly brewed, it is frequently had recourse to. A pound of good isinglass will make about 12 gallons of *finings*. It is cut into slender shreds, and put into a tub with as much vinegar or hard beer as will cover it, in order that it may swell and dissolve. In proportion as the solution proceeds, more beer must be poured upon it, but it need not be so acidulous as the first, because, when once well softened by the vinegar, it readily dissolves. The mixture should be frequently agitated with a bundle of rods, till it acquires the uniform consistence of thin treacle, when it must be equalized still more by passing through a tammy cloth, or a sieve. It may now be made up with beer to the proper measure of dilution. The quantity generally used is from a pint to a quart per barrel, more or less, according to the foulness of the beer. But before putting it into the butt, it should be diffused through a considerable volume of the beer with a whisk, till a frothy head be raised upon it. It is in this state to be poured into the cask, briskly stirred about; after which the cask must be bunged down for at least 24 hours, when the liquor should be limpid. Sometimes the beer will not be improved by this treatment; but this should be ascertained beforehand, by drawing off some of the beer into a cylindric jar or vial, and adding to it a little of the finings. After shaking and setting down the glass, we shall observe whether the feculencies begin to collect in flocky parcels, which slowly subside; or whether the isinglass falls to the bottom without making any impression upon the beer. This is always the case when the fermentation is incomplete, or a secondary decomposition has begun. Mr. Jackson has accounted for this clarifying effect of isinglass in the following way.

The isinglass, he thinks, is first of all rather diffused mechanically, than chemically dissolved, in the sour beer or vinegar, so that when the finings are put into the foul beer, the gelatinous fibres, being set free in the liquor, attract and unite with the floating feculencies, which before this union were of the same specific gravity with the beer, and therefore could not subside alone; but having now acquired additional weight by the coating of fish glue, precipitate as a flocculent magma. This is Mr. Jackson's explanation; to which I would add, that if there be the slightest disengagement of carbonic acid gas, it will keep up an obscure locomotion in the particles, which will prevent the said light impurities, either alone or when coated with isinglass, from subsiding. The beer is then properly enough called *stubborn* by the coopers. But the true theory of the action of isinglass is, that the tannin of the hops combines with the fluid gelatine, and forms a flocculent mass, which envelopes the muddy particles of the beer, and carries them to the bottom as it falls, and forms a sediment. When, after the finings are poured in, no proper precipitate ensues, it may be made to appear by the addition of a little decoction of hop.

Mr. Richardson, the author of the well-known brewer's saccharometer, gives the following as the densities of different kinds of beer:—

Beer.	Pounds per Barrel.	Specific Gravity.
Burton ale, 1st sort - - -	40 to 43	1·111 to 1·120
2d ditto - - -	35 to 40	1·097 to 1·111
3d ditto - - -	28 to 33	1·077 to 1·092
Common ale - - - - -	25 to 27	1·070 to 1·073
Ditto ditto - - - - - -	21	1·058
Porter, common sort - -	18	1·050
Ditto, double - - - -	20	1·055
Ditto, brown stout - - -	23	1·064
Ditto, best brown stout - -	26	1·072
Common small beer - - -	6	1·014
Good table beer - - - -	12 to 14	1·033 to 1·039

Of Returns or Malt Residuums.— When small beer is brewed after ale or porter, only one mash is to be made; but where this is not done, there may be two mashes, in order to economize malt to the utmost. We may let on the water at 160° or 165°, in any convenient quantity, infuse for an hour or thereby, then run it off, and pump into the copper, putting some hops into it, and causing it to boil for an instant; when it may be transferred to the cooler. A second mash or return may be made in the same manner, but at a heat 5° lower; and then disposed of in the boiler with some hops, which may remain in the copper during the night at a scalding heat, and may be discharged into the cooler in the morning. These two returns are to be let down into the underback immediately before the next brewing, and thence heated in the copper for the next

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mashing of fresh malt, instead of hot water, commonly called *liquor*, in the breweries. But allowance must be made, in the calculation of the worts, for the quantity of fermentable matter in these two returns. The nett aggregate saving is estimated from the gravity of the return taken when cold in the cooler. A slight economy is also made in the extra boiling of the used hops. The lapse of a day or two between the consecutive brewings is no objection to the method of *returns*, because they are too weak in saccharine matter to run any risk of fermentation.

In conclusion, it may be remarked that Mr. Richardson somewhat underrates the gravity of porter, which is now seldom under 20lbs. per barrel. The criterion for transferring from the gyle-tun to the cleansing butts is the attenuation caused by the production of alcohol in the beer: when that has fallen to 10lbs. or 11lbs., which it usually does in 48 hours, the cleansing process is commenced. The heat is at this time generally 75°, if it was pitched at 65°; for the heat and the attenuation go hand in hand.

About thirty years ago, it was customary for the London brewers of porter to keep immense stocks of it for eighteen months or two years, with the view of improving its quality. The beer was pumped from the cleansing butts into store-vats, holding from twenty to twenty-five gyles or brewings of several hundred barrels each. The store-vats had commonly a capacity of 5000 or 6000 barrels; and a few were double, and one was treble, this size. The porter, during its long repose in these vats, became fine, and by obscure fermentation its saccharine mucilage was nearly all converted into vinous liquor, and dissipated in carbonic acid. Its hop-bitter was also in a great degree decomposed. *Good hard beer* was the boast of the day. This was sometimes softened by the publican, by the addition of some mild new-brewed beer. Of late years, the taste of the metropolis has undergone such a complete revolution in this respect, that nothing but the mildest porter will now go down. Hence, six weeks is a long period for beer to be kept in London; and much of it is drunk when only a fortnight old. Ale is for the same reason come greatly into vogue; and the two greatest porter houses, Messrs. Barclay, Perkins, & Co., and Truman, Hanbury, & Co., have become extensive and successful brewers of mild ale, to please the changed palate of their customers.

We shall add a few observations upon the brewing of Scotch ale. This beverage is characterized by its pale amber color, and its mild balsamic flavor. The bitterness of the hop is so mellowed with the malt as not to predominate. The ale of Preston Pans is, in fact, the best substitute for wine which barley has hitherto produced. The low temperature at which the Scotch brewer pitches his fermenting tun restricts his labors to the colder months of the year. He does nothing during four of the summer months. He is extremely nice in selecting his malt and hops; the former being made from the best English barley, and the latter being the growth of Farnham or East Kent. The yeast is carefully looked after, and measured into the fermenting tun in the proportion of one gallon to 240 gallons of wort.

Only one mash is made by the Scotch ale brewer, and that pretty strong; but the malt is exhausted by eight or ten successive sprinklings of liquor (hot water) over the goods (malt), which are termed in the vernacular tongue, *sparges*. These waterings percolate through the malt on the mash-tun bottom, and extract as much of the saccharine matter as may be sufficient for the brewing. By this simple method much higher specific gravities may be obtained than would be practicable by a second mash. With malt, the infusion or saccharine fermentation of the *diastase* is finished with the first mash; and nothing remains but to wash away from the goods the matter which that process has rendered soluble. It will be found on trial that 20 barrels of wort drawn from a certain quantity of malt, by two successive mashings, will not be so rich in fermentable matter as 20 barrels extracted by ten successive sparges of two barrels each. The grains always remain soaked with wort like that just drawn off, and the total residual quantity is three fourths of a barrel for every quarter of malt. The gravity of this residual wort will on the first plan be equal to that of the second mash; but on the second plan, it will be equal only to that of the tenth sparge, and will be more attenuated in a very high geometrical ratio. The only serious objection to the sparging system is the loss of time by the successive drainages. A mash-tun with a steam jacket promises to suit the sparging system well; as it would keep up a uniform temperature in the goods, without requiring them to be sparged with very hot liquor.

The first part of the Scotch process seems of doubtful economy; for the mash liquor is heated so high as 180°. After mashing for about half an hour, or till every particle of the malt is thoroughly drenched, the tun is covered, and the mixture left to infuse about three hours; it is then drained off into the under-back, or preferably into the wort copper.

After this wort is run off, a quantity of liquor (water), at 180° of heat, is sprinkled uniformly over the surface of the malt; being first dashed on a perforated circular board, suspended horizontally over the mash-tun, wherefrom it descends like a shower upon the whole of the goods. The percolating wort is allowed to flow off, by three or more small stopcocks round the circumference of the mash-tun, to ensure the equal diffusion of the liquor.

The first sparge being run off in the course of twenty minutes, another similar one is affused; and thus in succession till the whole of the drainage, when mixed with the first mash-wort, constitutes the density adapted to the quality of the ale. Thus, the strong worts are prepared, and the malt is exhausted either for table beer, or for a *return*, as pointed out above. The last sparges are made 5° or 6° cooler than the first.

The quantity of hops seldom exceeds four pounds to the quarter of malt. The manner of boiling the worts is the same as that above described; but the conduct of the fermentation is peculiar. The heat is pitched at 50°, and the fermentation continues from a fortnight to three weeks. Were three brewings made in the week, seven or eight working tuns would thus be in constant action; and, as they are usually in one room, and some of them at an *elevation* of temperature of 15°, the apartment must be propitious to fermentation, however low its heat may be at the commencement. No more yeast is used than is indispensable; if a little more be needed, it is made effective by rousing up the tuns twice a day from the bottom.

When the progress of the attenuation becomes so slack as not to exceed half a pound in the day, it is prudent to cleanse, otherwise the top-barm might re-enter the body of the beer, and it would become *yeast-bitten*. When the ale is cleansed, the head, which has not been disturbed for some days, is allowed to float on the surface till the whole of the *then* pure ale is drawn off into the casks. This top is regarded as a sufficient preservative against the contact of the atmosphere. The Scotch do not skim their tuns, as the London ale brewers commonly do. The Scotch ale, when so cleansed, does not require to be set upon close stillions. It throws off little or no yeast, because the fermentation was nearly finished in the tun. The strength of the best Scotch ale ranges between 32 and 44 pounds to the barrel; or it has a specific gravity of from 1·088 to 1·122, according to the price at which it is sold. In a good fermentation, seldom more than a fourth of the original gravity of the wort remains at the period of the cleansing. Between one third and one fourth is the usual degree of attenuation. Scotch ale soon becomes fine, and is seldom racked for the home market. The following table will show the progress of fermentation in a brewing of good Scotch ale:

20 barrels of mash-worts of 42½ pounds gravity = 860·6
20 — returns $6\frac{1}{10}$ = 122

12) 982·6

pounds weight of extract per quarter of malt = 81

Fermentation:—

March 24. pitched the tun at 51°: yeast 4 gallons.

	Temp.	Gravity.	
25.	52°	41	pounds.
28.	56°	39	
30.	60°	34	
April 1.	62°	32	
4.	65°	29	added 1 lb. of yeast.
5.	66°	25	
6.	67°	23	
7.	67°	20	
8.	66°	18	
9.	66°	15	
10.	64°	14·5	cleansed.*

The following table shows the origin and the result of fermentation, in a number of practical experiments:—

Original Gravity of the Worts.	Lbs. per Barrel of Saccharine Matter.	Specific Gravity of the Ale.	Lbs. per Barrel of Saccharine Matter.	Attenuation, or Saccharum decomposed.
1·0950	88·75	1·0500	40·25	0·478
1·0918	85·62	1·0420	38·42	0·552
1·0829	78·125	1·0205	16·87	0·787
1·0862	80·625	1·0236	20·00	0·757
1·0780	73·75	1·0280	24·25	0·698
1·0700	65·00	1·0285	25·00	0·615
1·1002	93·75	1·0400	36·25	0·613

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* Brewing (Society for diffusing Useful Knowledge), p. 156.

Fermentation Table — *continued.*

Original Gravity of the Worts.	Lbs. per Barrel of Saccharine Matter.	Specific Gravity of the Ale.	Lbs. per Barrel of Saccharine Matter.	Attenuation, or Saccharum decomposed.
1·1025	95·93	1·0420	38·42	0·600
1·0978	91·56	1·0307	27·00	0·705
1·0956	89·37	1·0358	32·19	0·640
1·1130	105·82	1·0352	31·87	0·661
1·1092	102·187	1·0302	26·75	0·605
1·1171	110·00	1·0400	36·25	0·669
1·1030	96·40	1·0271	23·42	0·757
1·0660	61·25	1·0214	17·80	0·709

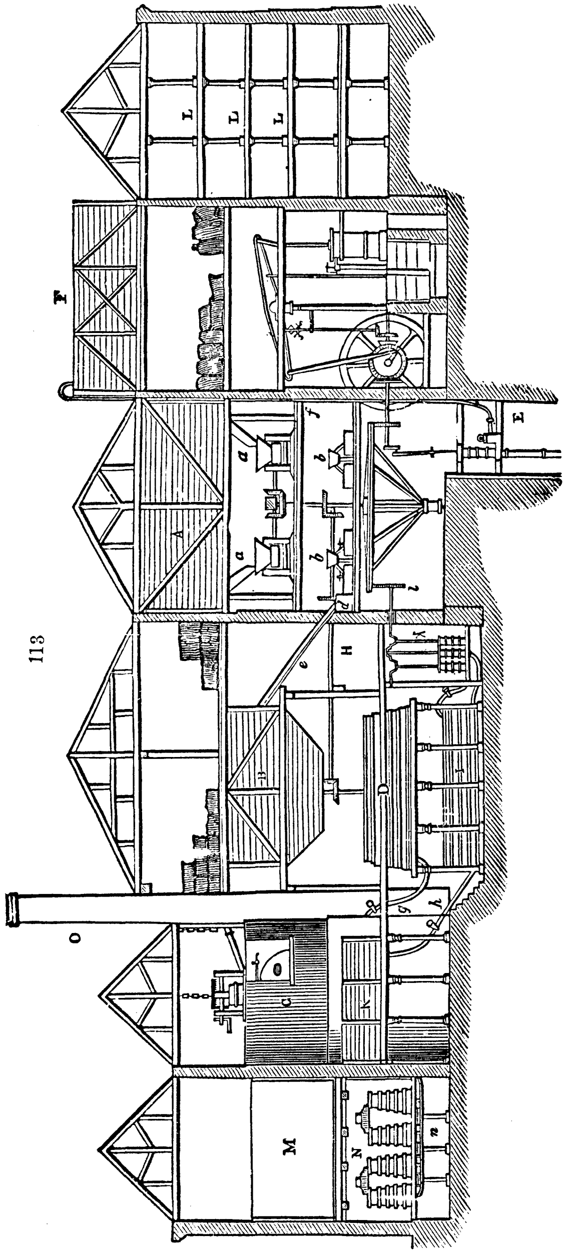
The second column here does not represent, I believe, the solid extract, but the pasty extract obtained as the basis of Mr. Allen's saccharometer, and therefore each of its numbers is somewhat too high. The last column, also, must be in some measure erroneous, on account of the quantity of acohol dissipated during the process of fermentation. It must be likewise incorrect, because the density due to the saccharine matter will be partly counteracted, by the effect of the alcohol present in the fermented liquor. In fact, the attenuation does not correspond to the strength of the wort; being greatest in the third brewing, and smallest in the first. The quantity of yeast for the above ale brewings in the table was, upon an average, one gallon for 108 gallons; but it varied with its quality, and with the state of the weather, which, when warm, permits much less to be used with propriety.

The good quality of the malt, and the right management of the mashing, may be tested by the quantity of saccharine matter contained in the successively drawn worts. With this view, an aliquot portion of each of them should be evaporated by a safety-bath heat to a nearly concrete consistence, and then mixed with twice its volume of strong spirit of wine. The truly saccharine substance will be dissolved, while the starch and other matters will be separated; after which the proportions of each may be determined by filtration and evaporation. Or an equally correct, and much more expeditious method of arriving at the same result would be, after agitating the viscid extract with the alcohol in a tall glass cylinder, to allow the insoluble fecula to subside, and then to determine the specific gravity of the supernatant liquid by a hydrometer. The additional density which the alcohol has acquired will indicate the quantity of malt sugar which it has received. The following table, constructed by me, at the request of Henry Warburton, Esq., M. P., chairman of the Molasses Committee of the House of Commons in 1830, will show the brewer the principle of this important inquiry. It exhibits the quantity in grains weight of sugar requisite to raise the specific gravity of a gallon of spirit of different densities to the gravity of water = 1·000:

Specific Gravity of Spirit.	Grains; Weight of Sugar in the Gallon Imperial.
0·995	980
0·990	1·890
0·985	2·800
0·980	3·710
0·975	4·690
0·970	5·600
0·965	6·650
0·960	7·070
0·955	8·400
0·950	9·310

The immediate purpose of this table was to show the effect of saccharine matter in disguising the presence or amount of alcohol in the weak feints of the distiller. But a similar table might easily be constructed, in which, taking a uniform quantity of alcohol of 0·825, for example, the quantity of sugar in any wort-extract would be shown by the increase of specific gravity which the alcohol received from agitation with a certain weight of the wort, inspissated to a nearly solid consistence by a safety-pan, made on the principle of my patent sugar-pan. (See Sugar.) Thus, the normal quantities being 1000 grain measures of alcohol, and 100 grains by weight of inspissated mash-extract, the hydrometer would at once indicate, by help of the table, first, the quantity per cent. of truly saccharine matter, and next, by subtraction, that of farinaceous matter present in it.

Plan, Machinery, and Utensils of a great Brewery.—*Figs.* 113 and 114 represent the arrangement of the utensils and machinery in a porter brewery on the largest scale; in which, however, it must be observed that the elevation *fig.* 113 is in a great degree imaginary as to the plane upon which it is taken; but the different vessels are arranged so as to explain their uses most readily, and at the same time to preserve, as nearly as possible, the relative positions which are usually assigned to each in works of this nature.



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The malt for the supply of the brewery is stored in vast granaries or malt-lofts, usually situated in the upper part of the buildings. Of these, I have been able to represent only one, at A, *fig.* 113: the others, which are supposed to be on each side of it, cannot be seen in this view. Immediately beneath the granary A, on the ground floor, is the mill; in the upper story above it, are two pairs of rollers, *figs*. 111, 112, and 113, under *a*, *a*, for bruising or crushing the grains of the malt. In the floor beneath the rollers are the mill-stones *b*, *b*, where the malt is sometimes ground, instead of being merely bruised by passing between the rollers, under *a*, *a*.

The malt, when prepared, is conveyed by a trough into a chest *d*, to the right of *b*, from which it can be elevated by the action of a spiral screw, *fig*. 115, enclosed in the sloping tube *e*, into the large chest or bin B, for holding ground malt, situated immediately over the mash-tun D. The malt is reserved in this bin till wanted, and it is then let down into the mashing-tun, where the extract is obtained by hot water supplied from the copper G, seen to the right of B.

The water for the service of the brewery is obtained from the well E, seen beneath the mill to the left, by a lifting pump worked by the steam engine; and the forcing-pipe *f* of this pump conveys the water up to the large reservoir or water-back F, placed at the top of the engine-house. From this cistern, iron pipes are laid to the copper G (on the right-hand side of the figure), as also to every part of the establishment where cold water can be wanted for cleaning and washing the vessels. The copper G can be filled with cold water by merely turning a cock; and the water, when boiled therein, is conveyed by the pipe *g* into the bottom of the mash-tun D. It is introduced beneath a false bottom, upon which the malt lies, and, rising up through the holes in the false bottom, it extracts the saccharine matter from the malt; a greater or less time being allowed for the infusion, according to circumstances. The instant the water is drawn off from the copper, fresh water must be let into it, in order to be ready for boiling the second mashing; because the copper must not be left empty for a moment, otherwise the intense heat of the fire would destroy its bottom. For the convenience of thus letting down at once as much liquor as will fill the lower part of the copper, a pan or second boiler is placed over the top of the copper, as seen in *fig*. 113; and the steam rising from the copper communicates a considerable degree of heat to the contents of the pan, without any expense of fuel. This will be more minutely explained hereafter. (*See fig*. 117.)

During the process of mashing, the malt is agitated in the mash-tun so as to expose every part to the action of the water. This is done by a mechanism contained within the mash-tun, which is put in motion by a horizontal shaft above it, H, leading from the mill. The mash machine is shown separately in *fig*. 116. When the operation of mashing is finished, the wort or extract is drained down from the malt into the vessel I, called the *under-back*, immediately below the mash-tun, of like dimensions, and situated always on a lower level, for which reason it has received this name. Here the wort does not remain longer than is necessary to drain off the whole of it from the tun above. It is then pumped up by the three-barrelled pump *k*, into the pan upon the top of the copper, by a pipe which cannot be seen in this section. The wort remains in the pan until the water for the succeeding mashes is discharged from the copper. But this delay is no loss of time, because the heat of the copper, and the steam arising from it, prepare the wort, which had become cooler, for boiling. The instant the copper is emptied, the first wort is let down from the pan into the copper, and the second wort is pumped up from the under-back into the upper pan. The proper proportion of hops is thrown into the copper through the near hole, and then the door is shut down, and screwed fast, to keep in the steam, and cause it to rise up through pipes into the pan. It is thus forced to blow up through the wort in the pan, and communicates so much heat to it, or water, called *liquor* by the brewers, that either is brought near to the boiling point. The different worts succeed each other through all the different vessels with the greatest regularity, so that there is no loss of time, but every part of the apparatus is constantly employed. When the ebullition has continued a sufficient period to coagulate the grosser part of the extract, and to evaporate part of the water, the contents of the copper are run off through a large cock into the *jack-back* K, below G, which is a vessel of sufficient dimensions to contain it, and provided with a bottom of cast-iron plates, perforated with small holes, through which the wort drains and leaves the hops. The hot wort is drawn off from the jack-back through the pipe *h* by the three-barrelled pump, which throws it up to the coolers L, L, L; this pump being made with different pipes and cocks of communication, to serve all the purposes of the brewery except that of raising the cold water from the well. The coolers L, L, L, are very shallow vessels, built over one another in several stages: and that part of the building in which they are contained is built with lattice-work or shutter flaps, on all sides, to admit free currents of air. When the wort is sufficiently cooled to be put to the first fermentation, it is conducted in pipes from all the different coolers to the large fermenting vessel or gyle-tun M, which, with another similar vessel behind it, is of sufficient capacity to contain all the beer of one day's brewings.

Whenever the first fermentation is concluded, the beer is drawn off from the great fermenting vessel M, into the small fermenting casks or cleansing vessels N, of which there are a great number in the brewery. They are placed four together, and to each four a com-

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mon spout is provided to carry off the yeast, and conduct it into the troughs *u*, placed beneath. In these cleansing vessels the beer remains till the fermentation is completed; and it is then put into the store-vats, which are casks or tuns of an immense size, where it is kept till wanted, and is finally drawn off into barrels, and sent away from the brewery. The store-vats are not represented in the figure: they are of a conical shape, and of different dimensions, from fifteen to twenty feet diameter, and usually from fifteen to twenty feet in depth. The steam-engine which puts all the machine in motion is exhibited in its place, on the left side of the figure. On the axis of the large fly-wheel is a bevelled spur-wheel, which turns another similar wheel upon the end of a horizontal shaft, which extends from the engine-house to the great horse-wheel, set in motion by means of a spur-wheel. The horse-wheel drives all the pinions for the mill-stones *b b*, and also the horizontal axis which works the three-barrelled pump *k*. The rollers *a*, *a*, are turned by a bevel wheel upon the upper end of the axis of the horse-wheel, which is prolonged for that purpose; and the horizontal shaft H, for the mashing engine, is driven by a pair of bevel wheels. There is likewise a sack-tackle, which is not represented. It is a machine for drawing up the sacks of malt from the court-yard to the highest part of the building, whence the sacks are wheeled on a truck to the malt-loft A, and the contents of the sacks are discharged.

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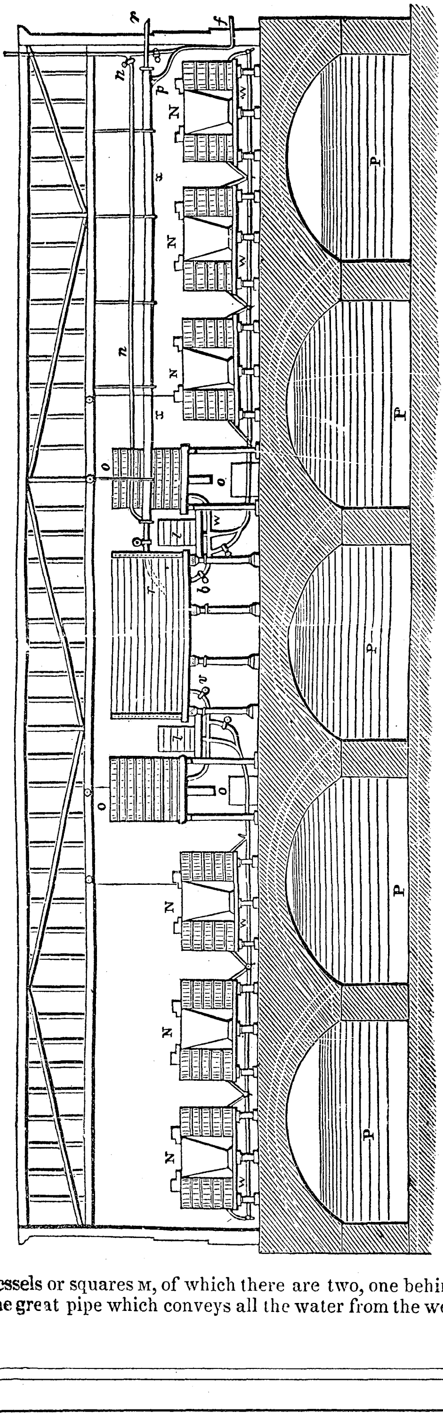

The horse-wheel is intended to be driven by horses occasionally, if the steam-engine should fail; but these engines are now brought to such perfection that it is very seldom any recourse of this kind is needed.

Fig. 114 is a representation of the *fermenting house* at the brewery of Messrs. Whitbread and Company, Chiswell Street, London, which is one of the most complete in its arrangement in the world: it was erected after the plan of Mr. Richardson, who conducts the brewing at those works. The whole of *fig.* 114 is to be considered as devoted to the same object as the large vessel M and the casks N, *fig.* 113. In *fig.* 114 *r r* is the pipe which leads from the different coolers to convey the wort to the great fermenting vessels or squares M, of which there are two, one behind the other; *f f* represents a part of the great pipe which conveys all the water from the well E, *fig.* 113, up to the water cistern

F. This pipe is conducted purposely up the wall of the fermenting-house, *fig.* 114, and has a cock in it, near *r*, to stop the passage. Just beneath this passage a branch-pipe *p* proceeds, and enters a large pipe *x x*, which has the former pipe *r* withinside of it. From the end of the pipe *x*, nearest to the squares M, another branch *n n* proceeds, and returns to the original pipe *f*, with a cock to regulate it. The object of this arrangement is to make all, or any part, of the cold water flow through the pipe *x x*, which surrounds the pipe *r*, formed only of thin copper, and thus cool the wort passing through the pipe *r*, until it is found by the thermometer to have the exact temperature which is desirable before it is put to ferment in the great square M. By means of the cocks at *n* and *p*, the quantity of cold water passing over the surface of the pipe *r* can be regulated at pleasure, whereby the heat of the wort, when it enters into the square, may be adjusted within half a degree.

When the first fermentation in the squares M M is finished, the beer is drawn off from them by pipes marked *v*, and conducted by its branches W W W, to the different rows of fermenting-tuns, marked N N, which occupy the greater part of the building. In the hollow between every two rows are placed large troughs, to contain the yeast which they throw off. The figure shows that the small tuns are all placed on a lower level than the bottom of the great vessels M, so that the beer will flow into them, and, by hydrostatic equilibrium, will fill them to the same level. When they are filled, the communication-cock is shut; but, as the working off the yeast diminishes the quantity of beer in each vessel, it is necessary to replenish them from time to time. For this purpose, the two large vats O O are filled from the great squares M M, before any beer is drawn off into the small casks N, and this quantity of beer is reserved at the higher level for filling up. The two vessels O O are, in reality, situated between the two squares M M; but I have been obliged to place them thus in the section, in order that they may be seen. Near each filling-up tun O is a small cistern *t* communicating with the tun O by a pipe, which is closed by a float-valve. The small cisterns *t* are always in communication with the pipes which lead to the small fermenting vessels N; and therefore the surface of the beer in all the tuns, and in the cisterns, will always be at the same level; and as this level subsides by the working off of the yeast from the tuns, the float sinks and opens the valve, so as to admit a sufficiency of beer from the filling-up tuns O, to restore the surfaces of the beer in all the tuns, and also in the cistern *t*, to the original level. In order to carry off the yeast which is produced by the fermentation of the beer in the tuns O O, a conical iron dish or funnel is made to float upon the surface of the beer which they contain; and from the centre of this funnel a pipe, *o*, descends, and passes through the bottom of the tun, being packed with a collar of leather, so as to be water-tight; at the same time that it is at liberty to slide down, as the surface of the beer descends in the tun. The yeast flows over the edge of this funnel-shaped dish, and is conveyed down the pipe to a trough beneath.

Beneath the fermenting-house are large arched vaults, P, built with stone, and lined with stucco. Into these the beer is let down in casks when sufficiently fermented, and is kept in store till wanted. These vaults are used at Mr. Whitbread's brewery, instead of the great store-vats of which we have before spoken, and are in some respects preferable, because they preserve a great equality of temperature, being beneath the surface of the earth.

The malt-rollers, or machines for bruising the grains of the malt, *figs.* 111, 112, have been already described. The malt is shot down from A, *fig.* 113, the malt-loft, into the hopper; and from this it is let out gradually through a sluice or sliding shuttle, *a*, *fig.* 113, and falls between the rollers.

Fig. 115, is the screw by which the ground or bruised malt is raised up, or conveyed from one part of the brewery to another. K is an inclined box or trough, in the centre of which the axis of the screw H is placed; the spiral iron plate or worm, which is fixed projecting from the axis, and which forms the screw, is made very nearly to fill the inside of the box. By this means, when the screw is turned round by the wheels E F, or by any other means, it raises up the malt from the box *d*, and delivers it at the spout G.

This screw is equally applicable for conveying the malt horizontally in the trough K, as slantingly; and similar machines are employed in various parts of breweries for conveying the malt wherever the situation of the works requires.

Fig. 116, is the mashing-machine. *a a* is the tun, made of wood staves, hooped together. In the centre of it rises a perpendicular shaft, *b*, which is turned slowly round by means of the bevelled wheels *t u* at the top. *c c* are two arms, projecting from that axis, and supporting the short vertical axis *d* of the spur-wheel *x*, which is turned by the spur-wheel *w*; so that, when the central axis *b* is made to revolve, it will carry the thick short axle *d* round the tun in a circle. That axle *d* is furnished with a number of arms, *e e*, which have blades placed obliquely to the plane of their motion. When the axis is turned round, these arms agitate the malt in the tun, and give it a constant tendency to rise upward from the bottom.

The motion of the axle *d* is produced by a wheel, *x*, on the upper end of it, which is turned by a wheel, *w*, fastened on the middle of the tube *b*, which turns freely round upon its central axis. Upon a higher point of the same tube *b* is a bevel wheel, *o*, receiving motion from a bevel wheel, *q*, fixed upon the end of the horizontal axis *n n*, which gives motion to the whole machine. This same axis has a pinion, *p*, upon it, which gives motion to the wheel *r*, fixed near the middle of a horizontal axle, which, at its left hand end, has a bevel pinion, *t*, working the wheel *u*, before mentioned. By these means, the rotation of the central axis *b* will be very slow compared with the motion of the axle *d;* for the latter will make seventeen or eighteen revolutions on its own axis in the same space of time that it will be carried once round the tun by the motion of the shaft *b*. At the beginning of the operation of mashing, the machine is made to turn with a slow motion; but, after having wetted all the malt by one revolution, it is driven quicker. For this purpose, the ascending shaft *f g*, which gives

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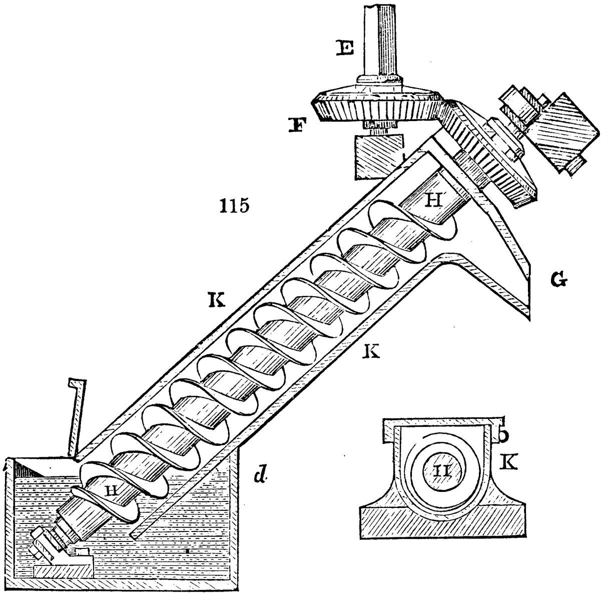

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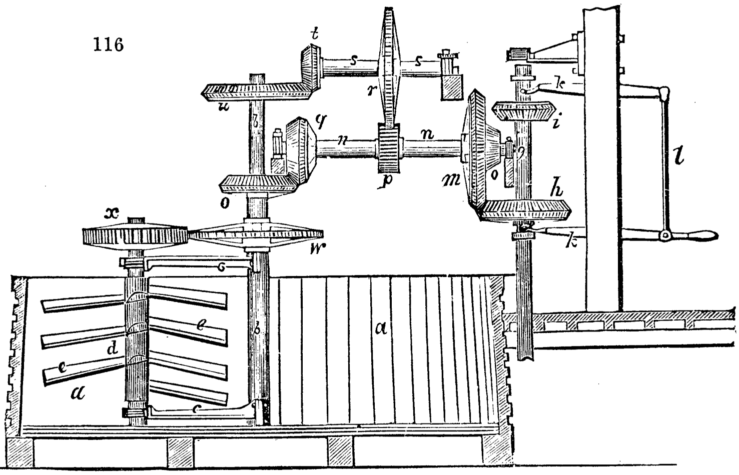

motion to the machine, has two level wheels, *h i*, fixed upon a tube, *f g*, which is, fitted upon a central shaft. These wheels actuate the wheels *m* and *o*, upon the end of the horizontal shaft *n n;* but the distance between the two wheels *h* and *i* is such, that they cannot be engaged both at once with the wheels *m* and *o;* but the tube *f g*, to which they are fixed, is capable of sliding up and down on its central axis sufficiently to bring either wheel *h* or *i* into gear with its corresponding wheel *o* or *m*, upon the horizontal shaft; and as the diameters of *n o*, and *i m*, are of very different proportions, the velocity of the motion of the machine can be varied at pleasure, by using one or other. *k* and *k* are two levers, which are forked at their extremities, and embrace collars at the ends of the tube *f g*. These levers being united by a rod, *l*, the handle *k* gives the means of moving the tube *f g*, and its wheels *h i*, up or down, to throw either the one or the other wheel into gear.

The object of boiling the wort is not merely evaporation and concentration, but extraction, coagulation, and, finally, combination with the hops; urposes which are better accomplished in a deep confined copper, by a moderate heat, than in an open shallow pan with a quick fire. The copper, being incased above in brickwork, retains its digesting temperature much longer than the pan could do. The waste steam of the close kettle, moreover, can be economically employed in communicating heat to water or weak worts; whereas the exhalations from an open pan would prove a nuisance, and would need to be carried off by a hood. The boiling has a four-fold effect: 1. it concentrates the wort; 2. during the earlier stages of heating, it converts the starch into sugar, dextrine, and gum, by means of the diastase; 3. it extracts the substance of the hops diffused through the wort; 4. it coagulates the albuminous matter present in the grain, or precipitates it by means of the tannin of the hops.

The degree of evaporation is regulated by the nature of the wort, and the quality of the beer. Strong ale and stout for keeping, require more boiling than ordinary porter or table-beer brewed for immediate use. The proportion of the water carried off by evaporation is usually from a seventh to a sixth of the volume. The hops are introduced during the progress of the ebullition. They serve to give the beer not only a bitter aromatic taste, but also a keeping quality, or they counteract its natural tendency to become sour; an effect partly due to the precipitation of the albumen and starch, by their resinous and tanning constituents, and partly to the antifermentable properties of their lupuline, bitter principle, ethereous oil, and resin. In these respects, there is none of the bitter plants which can be substituted for hops with advantage. For strong beer, powerful fresh hops should be selected; for weaker beer, an older and weaker article will suffice.

The hops are either boiled with the whole body of the wort, or extracted with a portion of it; and this concentrated extract added to the rest. The stronger the hops are, the longer time they require for extraction of their virtues; for strong hops, an hour and a half or two hours boiling may be proper; for a weaker sort, half an hour or an hour may be sufficient; but it is never advisable to push this process too far, lest a disagreeable bitterness, without aroma, be imparted to the beer. In our breweries, it is the practice to boil the hops with a part of the wort, and to filter the decoction through a drainer, called the *jack hop-back*. The proportion of hops to malt is very various; but, in general, from a pound and a quarter to a pound and a half of the former are taken for 100 lbs. of the latter in making good table-beer. For porter and strong ale, 2 pounds of hops are used, or even more; for instance, one pound of hops to a bushel of malt, if the beer be destined for the consumption of India.

During the boiling of the two ingredients, much coagulated albuminous matter, in various states of combination, makes its appearance in the liquid, constituting what is called the *breaking or curdling of the wort,* when numerous minute flocks are seen floating in it. The resinous, bitter, and oily-ethereous principles of the hops combine with the sugar and gum, or dextrine of the wort; but for this effect they require time and heat; showing that the boil is not a process of mere evaporation, but one of chemical reaction. A yellowish-green pellicle of hop-oil and resin appears upon the surface of the boiling wort, in a somewhat frothy form: when this disappears, the boiling is presumed to be completed, and the beer is strained off into the cooler. The residuary hops may be pressed and used for an inferior quality of beer; or they may be boiled with fresh wort, and be added to the next brewing charge.

Figs. 117,118, represent the copper of a London brewery. *Fig.* 117 is a vertical section; *fig.* 118, a ground-plan of the fire-grate and flue, upon a smaller scale: *a* is the close copper kettle, having its bottom convex within; *b* is the open pan placed upon its top. From the upper part of the copper, a wide tube, *c*, ascends, to carry off the steam generated during the ebullition of the wort, which is conducted through four downwards-slanting tubes, *d d* (two only are visible in this section), into the liquor of the pan *b*, in order to warm its contents. A vertical iron shaft or spindle, *e*, passes down through the tube *c*, nearly to the bottom of the copper, and is there mounted with an iron arm, called a

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rouser, which carries round a chain hung in loops, to prevent the hops from adhering to the bottom of the boiler. Three bent stays, *f*, are stretched across the interior, to support the shaft by a collet at their middle junction. The shaft carries at its upper end a bevel wheel, *g*, working into a bevel pinion upon the axis *h*, which may be turned either by power or by hand. The *rouser* shaft may be lifted by means of the chain *i*, which, going over two pulleys, has its end passed round the wheel and axle *k*, and is turned by a winch: *l* is a tube for conveying the waste steam into the chimney *m*.

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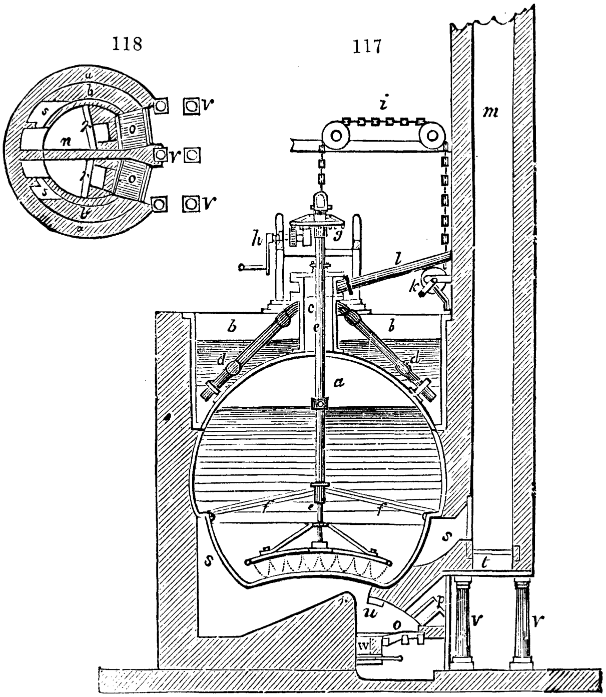

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The heat is applied as follows:—For heating the colossal coppers of the London breweries, two separate fires are required, which are separated by a narrow wall of brickwork, *n*, *figs.* 117, 118. The dotted circle *a' a'* indicates the largest circumference of the copper, and *b' b'* its bottom; *o o* are the grates upon which the coals are thrown, not through folding doors (as of old), but through a short slanting iron hopper, shown at *p*, *fig.* 117, built in the wall, and kept constantly filled with the fuel, in order to exclude the air. Thus the lower stratum of coals gets ignited before it reaches the grate. Above the hopper *p*, a narrow channel is provided for the admission of atmospherical air, in such quantity merely as may be requisite to complete the combustion of the smoke of the coals. Behind each grate there is a fire-bridge, *r*, which reflects the flame upwards, and causes it to play upon the bottom of the copper. The burnt air then passes round the copper in a semicircular flue, *s s*, from which it flows off into the chimney *m*, on whose under end a sliding damper-plate, *t*, is placed for tempering the draught. When cold air is admitted at this orifice, the combustion of the fuel is immediately checked. There is, besides, another slide-plate at the entrance of the slanting flue into the vertical chimney, for regulating the play of the flame under and around the copper. If the plate *t* be opened, and the other plate shut, the power of the fire is suspended, as it ought to be, at the time of emptying the copper. Immediately over the grate is a brick arch, *u*, to protect the front edge of the copper from the first impulsion of the flame. The chimney is supported upon iron pillars, *v*, *v*; *w* is a cavity closed with a slide-plate, through which the ashes may be taken out from behind, by means of a long iron hook.

Fig. 119 represents one of the sluice-cocks, which are used to make the communications of the pipes with the pumps, or other parts of the brewery. B B represents the pipe in which the cock is placed. The two parts of this pipe are screwed to the side of a box, C C, in which a slider, A, rises and falls, and intercepts, at pleasure, the passage of the pipe. The slider is moved by the rod *a*. This passes through a stuffing-box, in the top of the box which contains the slider, and has the rack *b* fastened to it. The rack is moved by a pinion fixed upon the axis of a handle *e*, and the rack and pinion are contained in a frame *d* which is supported by two pillars. The frame contains a small roller behind the rack, which bears it up towards the pinion, and keeps its teeth up to the teeth of the pinion. The slider A is made to fit accurately against the internal surface of the box C, and to bear against this surface by the pressure of a spring, so as to make a perfectly close fitting.

Fig. 120 is a small cock to be placed in the side of the great store vats, for the purpose of drawing off a small quantity of beer to taste and try its quality. A is a

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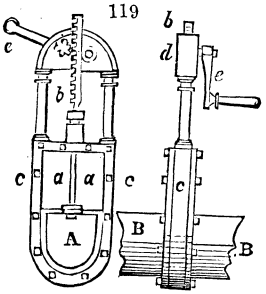

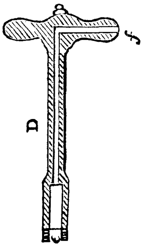

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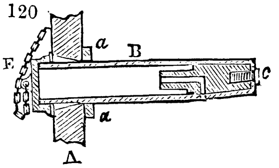
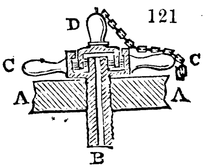


part of the stave or thickness of the great store vat; into this the tube B of the cock is fitted, and is held tight in its place by a nut, *a*, *a*, screwed on withinside. At the other end of the tube B, a plug, C, is fitted, by grinding it into a cone, and it is kept in by a screw. This plug has a hole up the centre of it, and from this a hole proceeds side-wise, and corresponds with a hole made through the side of the tube when the cock is open; but when the plug *c* is turned round, the hole will not coincide, and then the cock will be shut. D is the handle or key of the cock, by which its plug is turned to open or shut it: this handle is put up the bore of the tube (the cover E being first unscrewed and removed), and the end of it is adapted to fit the end of the plug of the cock. The handle has a tube or passage bored up it, to convey the beer away from the cock when it is opened, and from this the passage *f*, through the handle, leads, to draw the beer into a glass or tumbler. The hole in the side of the plug is so arranged, that, when the handle is turned into a perpendicular direction, with the passage *f* downwards, the cock will be open. The intention of this contrivance is, that there shall be no considerable projection beyond the surface of the tun; because it sometimes happens that a great hoop of the tun breaks, and, falling down, its great weight would strike out any cock which had a projection; and, if this happened in the night, much beer might be lost before it was discovered. The cock above described, being almost wholly withinside, and having scarcely any projection beyond the outside surface of the tun, is secure from this accident.

Fig. 121 is a small contrivance of a vent peg, to be screwed into the head of a common cask when the beer is to be drawn off from it, and it is necessary to admit some air to allow the beer to flow. A A represents a portion of the head of the cask into which the tube B is screwed. The top of this tube is surrounded by a small cup, from which project the two small handles C C, by which the peg is turned round to screw it into the cask. The cup round the other part of the tube is filled with water; into this a small cup, D, is inverted; in consequence, the air can gain admission into the cask when the pressure within is so far diminished, that the air will bubble up through the water, and enter beneath the small cup D.

121



The most efficient substance for fining beer hitherto discovered is isinglass, which is prepared by solution in vinegar or old stale beer, and this solution is afterwards reduced with thin mild beer generally brewed for the purpose, in all large establishments, from a raw or return wort. It must next be passed through a fine hair sieve, by means of rubbing it down with a hard hair-brush, and brought to the proper consistency by thin mild beer. If properly made, it will be clear, transparent, and free from feculencies. Finings serve excellently to remove any extraneous matter that may be found floating in the beer, and thus changes it from bright to brilliant. The common quantity used is from a pint to a quart per barrel, according to the nature of the beer.

To ascertain whether the beer is in a fit state for fining, put it into a long glass cylindric vessel, and add to it a teaspoonful, or thereby, of the fining; then give the mixture a good shake, by turning the vessel up and down, after closing its mouth with the palm of the hand. If the beer has been well brewed, its aptitude to become bright will be soon shown by the mixture getting thick and curdy; a bright portion will generally show itself at the bottom or middle; after which the finings will gradually mount to the top, taking up all the impurities along with them, till the whole becomes brilliant. Some have said that the finings should carry the impurities down to the bottom; but this, according to Mr. Black,* takes place only with stubborn beer, which would not become thoroughly bright with any quantity of finings which could be introduced. Finings have usually a specific gravity of from 1·010 to 1·016, and, when added to beer in a fit condition for fining, invariably go to the top, and not to the bottom. In fining beer in a barrel laid on its side, if the finings do not make their appearance at the bung-hole, the beer will not become bright. The isinglass must not be dissolved with heat, nor in hot water.

Beer brewed from imperfectly malted grain, or from a mixture of malt and raw corn, gives a fermentation quite different in flavor from that of beer from sound malt. The nose is, in fact, the best guide to the experienced brewer for ascertaining whether his process is going on well or ill.

Ropiness is a morbid state of beer, which is best remedied, according to Mr. Black, by putting the beer into a vat with a false bottom, and adding, per barrel, 4 or 5 pounds of hops, taken gradually away after the first boilings of the worts; and to them may be added about half a pound per barrel of mustard-seed. Rouse the beer as the hops are gradually introduced, and, in some months, the ropiness will be perfectly cured. The beer should be drawn off from below the false bottom.

For theoretical views, see FERMENTATION; and for wort-cooling apparatus, see REFRIGERATOR.

The quantity of beer and ale exported from the United Kingdom amounted in 1850 to 182,480 barrels, and in 1851 to 191,639; the declared value being respectively 558,794*l.*, and 577,874*l.*

BEER (BAVARIAN). The Germans from time immemorial have been habitually beer drinkers, and have exercised much of their technical and scientific skill in the production of beer of many different kinds, some of which are little known to our nation, while one at least, called Bavarian, possesses excellent qualities, entitling it to the attention of all brewers and consumers of this beverage. The peculiarities in the manufacture of Bavarian beer have recently attracted the attention of the most eminent chemists in Germany, especially of Professor Liebig, and much new light has thereby been thrown upon this curious portion of vegetable chemistry, which I shall endeavor to reflect upon the present article.

The following is a list of the principal beers at present brewed in Germany.

1. Brown beer of Merseburg; of pure barley malt.
2. — — barley malt and beet-root sugar.
3. — barley malt, potatoes, and beet-root syrup.
4. — refined beet-root syrup alone.
5. Covent or thin beer.
6. Berlin white beer, or the Champagne of the north.
7. Broyhan, a famous Hanoverian beer.
8. Double beer of Grünthal.
9. Bavarian beer; 1. Summer beer; 2. Winter beer.
10. — Bock-beer.
11. Wheat *Lager*-beer (slowly fermented).
12. White bitter beer of Erlangen.

Considerable interest among men of science, in favor of the Bavarian beer process, has been excited ever since the appearance of Liebig's Organic Chemistry, first published about twelve years ago. In the introduction to this admirable work, he says, "The beers of England and France, and the most parts of those of Germany, become gradually sour by contact of air. This defect does not belong to the beers of Bavaria, which may be preserved at pleasure in half-full casks, as well as full ones, without alteration in the air. This precious quality must be ascribed to a peculiar process employed for fermenting the wort, called in German *untergährung*, or fermentation from below; which has solved one of the finest theoretical problems.

"Wort is proportionally richer in soluble gluten than in sugar.† When it is set to ferment by the ordinary process, it evolves a large quantity of yeast, in the state of a thick froth, with bubbles of carbonic acid gas attached to it, whereby it is floated to the surface of the liquid. This phenomenon is easily explained. In the body of the wort along side of particles of sugar decomposing, there are particles of gluten being oxidized at the same time, and enveloping as it were the former particles, whence the carbonic acid of the sugar and the insoluble ferment from the gluten being simultaneously produced, should mutually adhere. When the metamorphosis of the sugar is completed, there remains still a large quantity of gluten dissolved in the fermented liquor, which gluten, in virtue of its tendency to appropriate oxygen, and to get decomposed, induces also the transformation of the alcohol into acetic acid (vinegar). But were all the matters susceptible of oxidizement as well as this vinegar ferment removed, the beer would thereby lose its faculty of becoming sour. These conditions are duly fulfilled in the process followed in Bavaria.

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* Treatise on Brewing, 8vo. p. 68.

† It does not surely contain more gluten than it does sugar; at least no experiments, known to me, prove this proposition.

"In that country the malt-wort is set to ferment in open backs, with an extensive surface, and placed in cool cellars, having an atmospheric temperature not exceeding 8° or 10° centigrade (46½° or 50° F.). The operation lasts from 3 to 4 weeks; the carbonic acid is disengaged, not in large bubbles that burst on the surface of the liquid, but in very small vesicles, like those of a mineral water, or of a liquor saturated with carbonic acid, when the pressure is removed. The surface of the fermenting wort is always in contact with the oxygen of the atmosphere, as it is hardly covered with froth, and as all the yeast is deposited at the bottom of the back under the form of a very viscid sediment, called in German *unterhefe*.

"In order to form an exact idea of the difference between the two processes of fermentation, it must be borne in mind that the metamorphosis of gluten and of azotized bodies in general is accomplished successively in two principal periods, and that it is in the *first* that the gluten is transformed in the interior of the liquid into an insoluble ferment, and that it separates alongside of the carbonic acid proceeding from the sugar. This separation is the consequence of an absorption of oxygen. It is, however, hardly possible to decide if this oxygen comes from the sugar, from the water, or even from an intestine change of the gluten itself, or, in other words, whether the oxygen combines directly with the gluten, to give it a higher degree of oxidation, or whether it lays hold of its hydrogen to form water.

"This oxidation of the gluten, from whichever cause, and the transformation of the sugar into carbonic acid and alcohol, are two actions so correlated, that by an exclusion of the one, the other is immediately stopped."

The *superficial* ferment (*oberhefe* in German) which covers the surface of the fermenting works is gluten oxidized in a state of putrefaction; and the ferment of *deposite* is the gluten oxidized in a state of *érémacausie.*

The surface yeast, or barm, excites in liquids containing sugar and gluten the same alteration which itself is undergoing, whereby the sugar and the gluten suffer a rapid and tumultuous metamorphosis. We may form an exact idea of the different states of these two kinds of yeast by comparing the *superficial* to vegetable matters putrefying at the bottom of a marsh, and the *bottom* yeast to the rotting of wood in a state of *érémacausie*, that is, of slow combustion. The peculiar condition of the elements of the *sediment* ferment causes them to act upon the elements of the sugar in an extremely slow manner, and excites the change into alcohol and carbonic acid, without that of the dissolved gluten.

Sugar, which at ordinary temperatures has no tendency to combine with oxygen, enters in the above predicament into fermentation; but the action is rendered much slower by the low temperature, while the affinity of the dissolved gluten for the oxygen of the air is aided by the contact of the sediment. The superficial yeast may be removed without stopping the fermentation, but the under yeast can not be removed without arresting all the phenomena of disoxidation of the second period. These would immediately cease; and if the temperature were now raised, they would be succeeded by the phenomena of the first period. The deposite does not excite the phenomena of tumultuous fermentation, for which reason it is totally unfit for panification (bread-baking), while the superficial yeast alone is suitable to this purpose.

If to wort at a temperature of from 46½° to 50° F. the top yeast be added, a quiet slow fermentation is produced, but one accompanied with a rising up of the mass, while yeast collects both at the surface and bottom of the backs. If this deposite be removed to make use of it in other operations, it requires by little and little the characters of the *unterhefe*, and becomes incapable of exciting the phenomena of the first fermenting period, causing only, of 59° F., those of the second; namely, sedimentary fermentation. It must be carefully observed that the right *unterhefe* is not the precipitate which falls to the bottom of backs in the ordinary fermentation of beer, but is a matter entirely different. Peculiar pains must be taken to get it genuine, and in a proper condition at the commencement. Hence the brewers of Hessia and Prussia, who wished to make Bavarian beer, found it more to their interest to send for the article to Wurtzburg, or Bamberg, in Bavaria, than to prepare it themselves. When once the due primary fermentation has been established and well regulated in a brewery, abundance of the true *unterhefe* may be obtained for all future operations.

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In a wort made to ferment at a low temperature with deposite only, the presence of the *unterhefe* is the first condition essential to the metamorphosis of the *saccharum*, but it is not competent to bring about the oxidation of the gluten dissolved in the wort, and its transformation into an insoluble state. This change must be accomplished at the cost of the atmospherical oxygen.

In the tendency of soluble gluten to absorb oxygen, and in the free access of the air, all the conditions necessary for its *érémacausis*, or slow combustion, are to be found It is known that the presence of oxygen and soluble gluten are also the conditions of acetification (vinegar-making), but they are not the only ones; for this process requires a temperature of a certain elevation for the alcohol to experience this slow combustion. Hence, by excluding that temperature, the combustion (oxidation) of alcohol is obstructed, while the gluten alone combines with the oxygen of the air. This property does not belong to alcohol at a low temperature, so that during the oxidation in this case of the gluten, the alcohol exists alongside of it, in the same condition as the gluten alongside of sulphurous acid in the *muted* wines. In wines not impregnated with the fumes of burning sulphur, the oxygen which would have combined at the same time with the gluten and the alcohol does not seize either of them in wines which have been subjected to *mutism*, but it unites itself to the sulphurous acid to convert it into the sulphuric. The action called *sedimentary* fermentation is therefore merely a simultaneous metamorphosis of putrefaction and slow combustion; the sugar and the *unterhefe* putrefy, and the soluble gluten gets oxidized, not at the expense of the oxygen of the water and the sugar, but of the oxygen of the air, and the gluten then falls in the insoluble state. The process of Appert for the preservation of provisions is founded upon the same principle as the Bavarian process of fermentation; in which all the putrescible matters are separated by the intervention of the air at a temperature too low for the alcohol to become oxidized. By removing them in this way, the tendency of the beer to grow sour, or to suffer a further change, is prevented. Appert's method consists in placing in presence of vegetables or meat which we wish to preserve the oxygen at a high temperature, so as to produce slow combustion, but without putrefaction or even fermentation. By removing the residuary oxygen after the combustion is finished, all the causes of an ulterior change are removed. In the sedimentary fermentation of beer, we remove the matter which *experiences* the combustion; whereas, on the contrary, in the method of Appert, we remove that which produces it.

It is uncertain whether the dissolved gluten, in being converted into insoluble yeast by the action of the oxygen, combines directly *with* the oxygen; that is to say, whether the yeast differs from the soluble gluten merely by having absorbed an additional quantity of oxygen. This question is in fact very difficult to solve by analysis. If the gluten be regarded as a hydrogenated combination, it is obvious that in the fermentation of wine-must, and malt-wort, the hydrogen will be carried off by the oxygen, and the action will then be the same as the transformation of alcohol into *aldehyde*. When the contact of the atmosphere is excluded, this oxygen can not evidently be derived from the elements of the air, or from those of the water; for it can not be supposed that oxygen will take hydrogen from the water, in order to recompose water with the hydrogen of the gluten. The elements of the *saccharum* must therefore furnish this oxygen; or in the course of the formation of the yeast, a portion of the sugar will be decomposed; but thts decomposition is not of the same kind as that which results from the immediate metamorphosis of the sugar into carbonic acid and alcohol; hence a certain portion of the sugar will afford neither alcohol nor carbonic acid, but it will yield less oxgenated products from its elements. These products occasion the great difference in the qualities of fermented liquors, and particularly in their alcoholic strength. In the ordinary fermentation of grape-juice and worts, these liquids do not furnish a quantity of alcohol equivalent to the sugar which they contain, because a certain portion of the sugar serves for the oxidation of the gluten, and is not transformed like the rest. But whenever the liquor has arrived at the second period, the product in alcohol ought to be equivalent to the quantity of sugar present, as happens in all fermentations which are not accompanied with a formation, but a disappearance of the yeast. It is well ascertained that worts furnish in the Bavarian breweries 10 or 20 per cent. more alcohol than they do by the ordinary process of fermentation. It is also a well-established fact that in the manufacture of spirits from potatoes, where no yeast is produced, or merely a quantity corresponding to the proportion of barley-malt added to the potato-wort, a quantity of alcohol may be produced, as also of carbonic acid, corresponding exactly to the quantity of carbon in the fecula employed. But, on the contrary, in the fermentation of beet-root juice, it is hardly possible to determine precisely, from the quantity of carbonic acid evolved, the quantity of sugar contained in the beets, for there is always less carbonic acid than the juice of the fresh root would furnish. In equal volumes, the beer made by the *unterhefe* process contains more alcohol, and is therefore more heady than that formed by the ordinary process.

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The temperature at which fermentation is carried on has a very marked influence upon the quantity of alcohol produced. It is known that the juice of beets set to ferment between 86° and 95 Fahr. does not yield alcohol, and its sugar is replaced by a less oxygenated substance, *mannite*, and lactic acid, resulting from the mucilage. In proportion as the temperature is lowered the mannite fermentation diminishes. As to azotized juices, however, it is hardly possible to define the conditions under which the transformation of the sugar will take place, without being accompanied with another decomposition which modifies its products. The fermentation of beer by *deposite* demonstrates that by the simultaneous action of the oxygen of the air and a low temperature, the metamorphosis of sugar is effected in a complete manner; for the vessels in which the operation is carried on are so disposed that the oxygen of the air may act upon a surface great enough to transform all the gluten into insoluble yeast, and thus to present to the sugar a matter constantly undergoing decomposition. The oxidizement of the dissolved gluten goes on, but that of the alcohol requires a higher temperature; whence it can not suffer eremacausis, that is, acetification, or conversion into vinegar.

At the beginning of the fermentation of must and wort, the quantity of matter undergoing change is obviously the largest. All the phenomena which accompany it, the disengagement of gas and the rise of temperature, are most active at this period, and in proportion as the decomposition advances, the external signs of it become less perceptible, without, however, disappearing completely before the transformation has reached its limit. The slow and continuous decomposition which succeeds to the rapid and violent disengagement of gases is denominated the *after* or *complementary* fermentation. For wine and beer it lasts till all the sugar has disappeared, so that the specific gravity of the liquors progressively diminishes during several months. This slow fermentation is in most cases a truly depositary fermentation; for by the progressive decomposition of the less, the sugar still in solution gets completely transformed; but when the air is excluded, that decomposition does not occasion the complete separation of the azotized matters in an insoluble shape.

In several states of the German confederation, the favorable influence of a rational process of fermentation upon the quality of the beers has been fully recognised. In the Grand Dutchy of Hesse considerable premiums were proposed for the brewing of beer according to the process pursued in Bavaria, which were decreed to those brewers who were able to prove that their product (neither strong nor highly hopped) had kept six months in the casks without becoming at all sour. When the first trials were being made several thousand barrels were spoiled, till eventually experience led to the discovery of the true practical conditions which theory had foreseen and prescribed.

Neither the richness in alcohol, nor in hops, nor both combined, can hinder ordinary beer from getting tart. In England, says Liebig, an immense capital is sacrificed to preserve the better sorts of ale and porter from souring, by leaving them for several years in enormous tuns quite full, and very well closed, while their tops are covered with sand. This treatment is identical with that applied to wines to make them deposite the wine-stone. A slight transpiration of air goes on in this case through the pores of the wood; but the quantity of azotized matter contained in the beer is so great, relatively to the proportion of oxygen admitted, that this element can not act upon the alcohol. And yet the beer thus managed will not keep sweet more than two months in smaller casks to which air has access. The grand secret of the Munich brewers is to conduct the fermentation of the wort at too low a temperature to permit of the acetification of the alcohol, and to cause all the azotized matters to be completely separated by the intervention of the oxygen of the air, and not by the sacrifice of the sugar, It is only in March and October that the good store beer is begun to be made in Bavaria.

In our ordinary breweries, the copious disengagement of carbonic acid from the frothy top of the fermenting tuns and gyles prevents the contact of oxygen from the worts; so that, as the gluten can not be oxidized by the air, it attracts oxygen from the sugar, and thus gives rise to several adventitious hydrogenated products, just as the fetid oil is generated in the rapid fermentation of spirit-wash by the distillers. In this case no inconsiderable portion of the gluten remains undecomposed in the beer, which, by its extreme proneness to corruption, afterward attracts oxygen greedily from the air, and, at temperature above 52°, imparts this *contact action* to the alcohol, and, by a species of infection, changes it into vinegar. Indeed, in most of the rapid fermentations a portion of vinegar is formed, which itself serves as an acetous ferment to the rest of the alcohol; whereas the result of the *bottom* fermentation is a beer free from vinegar, and certainly hardly a trace of gluten; so that it does not possess the conditions requisite to intestine change or deterioration. This perfection is, however, in my opinion, rarely attained. In my several journeys into Germany I have met with much spurious or ill-made Bavarian beer. The best contains, when brought to England, a little acid, but no perceptible gluten on the addition of ammonia in excess. Most of our beers, ales, &c., deposite more or less gluten when thus treated.

The following table exhibits the results of the chemical examinations of the undermentioned kinds of beer:—

Name of the Beer.	Quantity in 100 parts by weight				Analyst.
	Water.	Malt extr.	Alcohol.	Carb. acid.	
Augustine double beer—Munich - .	88·86	8·0	3·6	0·14	Kaiser.
Salvator beer — do. - -	87·62	8·0	4·2	0·18	Do.
Bock-beer, from the Royal brewery — do. -	88·64	7·2	4·0	0·16	Do.
Schenk (pot) beer, from a Bavarian country brewery; a kind of small beer -	92·94	4·0	2·9	0·16	Do.
Bock-beer of Brunswick, of the Bavarian kind -	88·50	6.50	5·0	- -	Balhorn.
Lager (store) beer, of Brunswick, of the Bavarian kind	91·0	5·4	3·50	- -	Otto.
Brunswick sweet small beer	84·70	14·0	1·30	- -	Do.
Brunswick mum - -	59·2	39·0	1.80	0·1	Kaiser.

Malting in Munich.—The barley is steeped till the acrospire, embryo, or seed-germ, seems to be quickened; a circumstance denoted by a swelling at the end of that ear which was attached to the foot-stalk, as also when, on pressing a pile between two fingers against the thumb-nail, a slight projection of the embryo is perceptible. As long, however, as the seed-germ sticks too firm to the husk, it has not been steeped enough for exposure on the underground malt-floor. Nor can deficient steeping be safely made up for afterward by sprinkling the malt-couch with a watering-can, which is apt to render the malting irregular. The steep-water should be changed repeatedly, according to the degree of foulness and hardness of the barley; first, six hours after immersion, having previously stirred the whole mass several times; afterward, in winter, every twenty-four hours, but in summer every twelve hours. It loses none of its substance in this way, whatever vulgar prejudice may think to the contrary. After letting off the last water from the stone cistern, the Bavarians leave the barley to drain in it during four or six hours. It is now taken out, and laid on the couch floor, in a square heap, eight or ten inches high, and it is turned over, morning and evening, with dexterity, so as to throw the middle portion upon the top and bottom of the new-made couch. When the acrospire has become as long as the grain itself, the malt is carried to the *withering* (*welkboden*) or drying-floor, in the open air, where it is exposed (in dry weather) during from eight to fourteen days, being daily turned over three times with a winnowing shovel. It is next dried on a well-constructed cylinder or flue-heated malt-kin, at a gentle clear heat, without being browned in the slightest degree, while it turns friable into a fine white meal. Smoked malt is entirely rejected by the best Bavarian brewers. Their malt is dried on a series of wove wire horizontal shelves, placed over each other; up through whose interstices or perforations streams of air, heated to only 122° Fahr., rise from the surfaces of rows of hot sheet-iron pipe-flues, arranged a little way below the shelves. Into these pipes the smoke and burned air of a little furnace on the ground are admitted. The whole is enclosed in a vaulted chamber, from whose top a large wooden pipe issues, for conveying away the steam from the drying malt. Each charge of malt may be completely dried on this kiln in the space of from eighteen to twenty-four hours, by a gentle uniform heat, which does not injure the diastase, or discolor the farina.*

The malt for store-beer should be kept three months at least before using it, and be freed by rubbing and sifting from the acrospires before being sent to the mill, where it should be crushed pretty fine. The barley employed is the best *distichon* or common kind, styled *hordeum vulgare.*

The hops are of the best and freshest growth of Bavaria, called the fine *spalter*, or *saatser Bohemian townhops*, and are twice as dear as the best ordinary hops of the rest of Germany. They are in such esteem as to be exported even into France.

The Bavarians are so much attached to the beer beverage, which they have enjoyed from their remotest ancestry, that they regard the use of distilled spirits, even in moderation, as so immoral a practice, as to disqualify dram-drinkers for decent society.

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* I have a set of designs of the Bavarian kiln, but I believe the above description will make its construction sufficiently intelligible.

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Their government has taken great pains to improve this national beverage, by encouraging the growth of the best qualities of hops and barley. The vaults in which the beer is fermented, ripened, and kept, are all underground, and mostly in stony excavations, called *felsenkeller* or rock-cellars. The beer is divided into two sorts, called *summer* and *winter*. The latter is light, and, being intended for immediate retail in tankards, is termed *schankbier*. The other, or the *lagerbier*, very sensibly increases in vinous strength in proportion as it decreases in sweetness, by the judicious management of the *nachgährung*, or fermentation in the casks. In several parts of Germany a keeping quality is communicated to beers by burning sulphur in the casks before filling them, or by the introduction of sulphite of lime. But the flavor thus imparted is disliked in Munich, Bayreuth, Regensburg, Nürnberg, Hof, and the other chief towns of Bavaria; instead of which a preservative virtue is sought for in an aromatic mineral or Tyrol *pitch*, with which the insides of the casks are carefully coated, and in which the ripe beer is kept and exported. In December and January, after the casks are charged with the summer or store-beer, the double doors of the cellars are closed, and lumps of ice are piled up against them, to prevent all access of warm air. The cellar is not opened till next August, in order to take out the beer for consumption. In these circumstances the beer becomes transparent like champagne wine; and, since but little carbonic acid gas has been disengaged, little or none of the additionally generated alcohol is lost by evaporation.

The winter or schank (pot) beer is brewed in the months of October, November, March, and April; but the summer or store-beer in December, January, and February, or the period of the coldest weather. For the former beer, the hopped worts are cooled down only to from 51° to 55°, but for the latter to from 41° to 42½° Fahr. The winter beer is also a little weaker than the summer beer, being intended to be sooner consumed; since four bushels* (Berlin measure) of fine, dry, sifted malt, of large heavy *hordeum vulgare distichon*, affords seven *eimers* of winter beer, but not more than from five and a half to six of summer beer.† At the second infusion of the worts, small beer is obtained to the amount of twenty quarts from the above quantity of malt. For the above quantity of winter beer, six pounds of middling hops are reckoned sufficient; but for the summer beer, from seven to eight pounds of the finest hops. The winter beer may be sent out to the publicans in barrels five days after the fermentation has been completed in the tuns, and, though not quite clear, it will become so in the course of six days; yet they generally do not serve it out in pots for two or three weeks. But the summer beer must be perfectly bright and still before it is racked off into casks for sale.

Statement of the Products of a Brewing of Bavarian Beer.—The quantity brewed is 41 Munich eimers (64 *maass*) = 85½ Berlin quarts; and 60 Berlin quarts = 1 eimer; or 24 Munich barrels (of 100 Berlin quarts each); 1 Munich eimer = 15 gallons imperial. The beer contains from 50 to 60 parts by weight, of dry saccharum in 1,000 parts.

Expenditure.	*Thaler.*	*Slbg.*
24 Berlin bushels of white kiln-dried barley, rather finely crushed, weighing from 12 to 13 cwts. - - - - - -	24	0
36 pounds of new fine *spalter* (parted) hops at 46 thalers the cwt. -	16	17
½ pound of Carageen moss, for clarifying - - - - -	0	3
1 quart of yeast.		
1 quart of Tyrol pitch - - - - - - - - -	11	0
Mash—tax (in Bavaria and Prussia) upon 12 cwts. malt, at the rate of 20 *silbergroschen* = 2*s*., the cwt. - - - - .	8	0
Cost of crushing - - - - - - - -	1	0
Fuel - - - - - - - - - - -	4	0
Wages of labor, in the brewhouse and vault - - -	6	0
Do. Do. for cooper in pitching the casks - - -	3	0
Sundry small expenses . - - - - - - -	2	10
Or 11*l*. 8*s*.	76	0
1 *thaler* = 30 *silbergroschen* = 3 shillings		
Deduct for the grains of 12 cwts. of malt, at 10 *silbergroschen*, or 1*s*. per cwt. = 4 *thalers*, and for the value in yeast produced = 2 *thalers* more - - - - - - - - -	6	0
Total neat expenditure = 10*l*. 10*s*. - - - - - -	70	0

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* An English quarter of grain is equal to 5 bushels (*scheffel*) and nearly one third Prussian measure.

† 1 Eimer Prussian = 15 English imperial gallons; one Munich *scheffel* is equal to four Berlin *scheffels*; 1 Lib. Munich = 1·235 *Eng. lbs. Avoird.*: 1 Lib. Berlin = 1·031 *lbs. Avoird.*

This cost for 42 eimers (1 eimer = 14¾ galls. Imp.) = 619½ gallons = 17·2 London porter barrels, amounts to 4½*d.* per gallon, or 12*s.* 2*d.* per barrel. By the above reckoning, a good profit accrues to the brewer, after allowing a liberal sum for the rent of premises, interest of capital, &c.

He has less profit from the summer beer. For a brewing of 33 eimers = 505 gallons Imp., containing from 60 to 65 pounds of saccharum in 1,000 pounds of the beer, by Hermstaedt's saccharometer.

Expenditure.

	Thaler.	*Slbg.*
24 Berlin scheffels of white kiln-dried barley-malt, weighing from 12 to 13 centners* - - - - - - - -	24	0
48 Berlin pounds of fresh Bavarian fine hops, at 46 thaler per centner	20	0
½ pound of Carageen moss - - - - -	0	3
1 quart setting yeast (*unterhefe*).		
1 centner pitch - - - - - - - -	11	0
Malt tax on 12 centners - - - - - - -	8	0
Crushing the malt - - - - - - -	1	0
Fuel - - - - - - - - -	4	0
Wages, 6 thalers; coopers' do., 3 thalers; and sundries, 3 th. 27 sq.	12	27
	81	0
Deduct for grains 4 thalers, and yeast 2 thalers - -	6	0
Neat cost - - - - -	75	0

This cost of 11*l.* 5*s.* for 505 gallons amounts to fully 5⅓*d.* per gallon, and 16*s.* 6*d.* the barrel.

The cost at Munich is 2½ thalers the eimer, and 4 thalers the barrel. The eimer of the summer beer, or *lagerbier*, is sold for 4 thalers. The publicans there, as in London, are known to add more or less water to their beer before retailing it.

The yeast (*unterhefe*) is carefully freed by a scraper from the portions of light top yeast that may have fallen to the bottom; the true *unterhefe* is then carefully sliced off from the slimy sediment on the wood.

In Munich the malt is moistened slightly 12 or 16 hours before crushing it, with from 2 to 3 *maas*† of water for every bushel; the malt being well dried, and several months old. The mash-tun into which the malt is immediately conveyed is, in middle-sized breweries, a round oaken tub, about 4½ feet deep, 10 feet in diameter at bottom and 9 at top, outside measure, containing about 6,000 Berlin quarts. Into this tun cold water is admitted late in the evening, to the amount of 25 quarts for each *scheffel*, or 600 quarts for the 24 *scheffels* of the ground malt, which are then shot in and stirred about and worked well about with the oars and rakes, till a uniform pasty is formed without lumps. It is left thus for three or four hours; 3,000 quarts of water being put into the copper, and made to boil; and 1,800 quarts are gradually run down into the mash-tun, and worked about in it, producing a mean temperature of 142·5° Fahr. After an hour's interval, during which the copper has been kept full, 1,800 additional quarts of water are run into the tun, with suitable mashing. The copper being now emptied of water, the mash-mixture from the tun is transferred into it, and brought quickly to the boiling point, with careful stirring to prevent its setting on the bottom and getting burned, and it is kept at that temperature for half an hour. When the mash rises by the ebullition, it needs no more stirring. This process is called, in Bavaria, boiling the thick mash, *dickmaisch kochen*. The mash is next returned to the tun, and well worked about in it. A few barrels of a thin mash-wort are kept ready to be put into the copper the moment it is emptied of the thick mash. After a quarter of an hour's repose the portion of liquid filtered through the sieve-part of the bottom of the tun into the wort-cistern is put into the copper, thrown back boiling hot into the mash in the tun, which is once more worked thoroughly.

The copper is next cleared out, filled up with water, which is made to boil for the after or small-beer brewing. After two hours settling in the open tun, the worts are drawn off clear.

Into the copper, filled up one foot high with the wort, the hops are introduced, and the mixture is made to boil during a quarter of an hour. This is called *roasting the hops*. The rest of the wort is now put into the copper, and boiled along with the hops during at least an hour or an hour and a half. The mixture is then laded out through the hop-filter into the cooling-cistern, where it stands three or four inches deep, and is exposed upon an extensive surface to natural or artificial currents of cold air, so as to be quickly cooled. For every 20 barrels of lagerbier, there are allowed 10 of small beer; so that 30 barrels of wort are made in all.

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* 1 Centner = 110 Prussian pounds = 113·44 lbs. Avoird.

† A Bavarian *maas* = 1¼ quarts English measure.

For the winter or pot-beer the worts are brought down to about 59° Fahr. in the cooler, and the beer is to be transferred into the fermenting-tuns at from 54·5° to 59° Fahr.; for the summer or *lagerbier*, the worts must be brought down in the cooler to from 43° to 45½°, and put into the fermenting-tuns at to from 41° to 43° Fahr.

A few hours beforehand, while the wort is still at the temperature of 63½° Fahr., a quantity of *lobb* must be made, called *vorstellen* (*fore-setting*) in German, by mixing the proportion of *unterhefe* (yeast) intended for the whole brewing with a barrel or a barrel and a half of the worts, in a small tub called the *gähr-tiene*, stirring them well together, so that they may immediately run into fermentation. This *lobb* is in this state to be added to the worts. The *lobb* is known to be ready when it is covered with a white froth from one quarter to one half an inch thick; during which it must be well covered up. The large fermenting-tun must in like manner be kept covered, even in the vault. The colder the worts, the more yeast must be used. For the above quantity, at

From 57° to 59° Fahr.,	6	*maas of unterhefe.*
53° to 55°	8	—
48° to 50°	10	—
41° to 33°	12	—

Some recommend that wort for this kind of fermentation (the *untergährung*) should be set with the yeast at from 48° to 57°; but the general practice at Munich is to set the summer *lager* beer at from 41° to 43° F.

By following the preceding directions, the wort in the tun should, in the course of from twelve to twenty-four hours, exhibit a white froth round the rim, and even a slight whiteness in the middle. After another twelve or twenty-four hours, the froth should appear in curls; and, in a third like period, these curls should be changed into a still higher frothy brownish mass. In from twenty-four to forty-eight hours more, the barm should have fallen down in portions through the beer, so as to allow it to be seen in certain points. In this case it may be turned over into the smaller ripening tuns in the course of other five or six days. But when the worts have been set to ferment at from 41° to 43° Fahr., they require from eight to nine days. The beer is transferred, after being freed from the top yeast by a skimmer, by means of the stopcock near the bottom of the large tun. It is either first run into an intermediate vessel, in order that the top and bottom portions may be well mixed, or into each of the *lager* casks, in a numbered series, like quantities of the top and bottom portions are introduced. In the ripening cellars the temperature can not be too low. The best keeping beer can never be brewed unless the temperature of the worts at setting, and of course the fermenting-vault, be as low as 50° F. In Bavaria, where this manufacture is carried on under government inspectors, a brewing period is prescribed by law, which is, for the under fermenting *lager* beer, from Michaelmas (29th September) to St. George (23d April). From the latter to the former period the ordinary top-barm beer alone is to be made. The ripening-casks must not be quite full, and they are to be closed merely with a loose bung, in order to allow of the working over of the ferment. But should the fermentation appear too languid, after six or eight days, a little briskly fermenting *lager* beer may be introduced. The *store* lager beer-tuns are not to be quite filled, so as to prevent all the yeasty particles from being discharged in the ripening fermentation; but the *pot* lager beer-tuns must be made quite full, as this beverage is intended for speedy sale within a few weeks of its being made.

As soon as the summer beer-vaults are charged with their ripening-casks, and with ice-cold air, they are closed air-tight with triple doors, having small intervals between, so that one may be entered and shut again, before the next is opened. These vaults are sometimes made in ranges radiating from a centre, and at others in rooms set off at right angles to a main gallery; so that in either case, when the external opening is well secured, with triple air-tight doors, it may be entered at any time, in order to inspect the interior, without the admission of warm air to the beer-barrels. The wooden bungs for loosely stopping them must be coated with the proper pitch, to prevent the possibility of their imparting any acetous ferment. In the *Beer Brewer** of A. F. Zimmermann, teacher of theoretical and practical brewing, who has devoted thirty-five years to this business, it is stated, that a ripened tun of lager or store-beer must be racked off all at once, for when it is left half full it becomes flat (*schaal*); and that the tun of pot *lager* beer must, if possible, be all drunk off in the same day it is tapped; because on the following day the beer gets an unpleasant taste, even when the bung has not been taken out, but only a small hole has been made, which is opened only at the time of drawing the beer, and is immediately closed again with a spigot. He ascribes this change to the loss of the carbonic acid gas, with which the beer has got strongly impregnated during the latter period of its ripening, while being kept in tightly-bunged casks. The residuums in these casks are, however, bottled up in Bavaria, whereby the beer, after some time, recovers its brisk and pungent taste. But the beer-topers in Bavaria, who are professedly very numerous, indulge so delicate and fastidious a palate, that when assembled in their favorite pot-house, they wait impatiently for the tapping of a fresh cask, and cease for a while to tipple whenever it is half empty, puffing the time away with their pipes till another fresh tap be made. In the well-frequented beer-shops of Munich a common-sized cask of *lager* beer is thus drank off in an hour. A reputation for superior brewing is there the readiest road to fortune.

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* *Der Bier-Brauer,* als Meister in seinem fache, &c., illustrates with many plates, Berlin, 1842.

Bock-Beer of Bavaria.—This is a favorite double strong beverage, of the best *lager* description, which is so named from causing its consumers to prance and tumble about like a buck or a goat; for the German word *bock* has both these meanings. It is merely a beer having a specific gravity one third greater, and is therefore made with a third greater proportion of malt, but with the same proportion of hops, and flavored with a few coriander-seeds. It has a somewhat darker color than the general *lager* beer, occasionally brownish, taste less bitter on account of the predominating malt, and somewhat aromatic. It is an eminently intoxicating beverage. It is brewed in December and January, and takes a long time to ferment and ripen; but still it contains too large a quantity of unchanged *saccharum* and *dextrine* for its hops, so that it tastes too luscious for habitual topers, and is drunk only from the beginning of May till the end of July, when the fashion and appetite for it are over for the year.

Statement of a Brewing of Bavarian Bock-Beer.

For 41 Bavarian eimers of 64 maass each (about 15 gallons Imperial) per *eimer*, or 615 gallons, nearly 17 barrels English in all:—

Expenditure.

	Thaler.	*Slbg.*
32 Berlin scheffels of the best pale malt freed from its acrospires, weighing 17½ centners, at 1 thaler per centner	32	0
48 lbs. (Berlin) of the best Bavarian hops	20	0
½ lb. Carageen moss for clarifying	0	3
1 lb. Coriander-seeds	0	1½
1 Quart setting yeast.		
1 Centner Tyrolese pitch	11	0
Malt-tax	11	20
Malt-crushing, fuel, wages, coopering, &c.	16	5½
Thalers of 3*s*. each	91	0
Deduct for the value of grains and yeast	7	0
Thalers of neat cost	84	0

This statement makes the eimer of the Bavarian bock-beer amount to about 2 thalers, or 6 shillings; being at the rate of nearly 5 pence per gallon; though without counting rent, interest of capital, or profit. It is, in fact, a malt or barley sweet wine or *liqueur;* but a very cheap one, as we see by this computation.

The chief difference in the process for making bock-beer lies in the mash-worts, and in the hops being boiled a shorter time, to preserve more of the aroma, and acquire less of the bitterness of the hop. The coriander-seeds are coarsely bruised, and added along with the hops and Carageen moss, to the boiling mash-worts, about twenty or thirty minutes before they are laded or drawn off into the mash-tun. Sometimes the hops are boiled apart in a little clear wort, as formerly described. The bock-beer is retailed in Munich at 3 silver groschen, about 3½*d*. the *seidel*, or pot, which is one English pint. The 25 gallon cask (*tonne*) is sold at 10 thalers, or 30 shillings. The publicans, therefore, have a very remunerating profit per pot, even supposing that they do not reduce the beer with water like our London craftsmen.

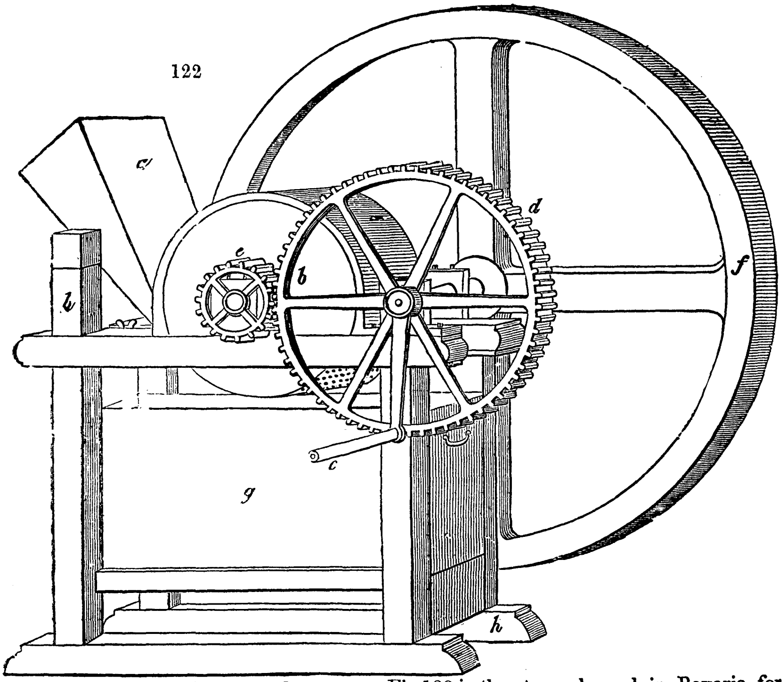
Zimmermann assumes the merit of having introduced Carageen moss as a clarifier into the beer manufacture. I do not know whether it may not have been used in this country for the same purpose, or in Ireland, where this *fucus* (*Chondra crispa*) grows abundantly. He says that 1 ounce of it is sufficient for 25 gallons of beer; and that it operates, not only in the act of boiling with the hops, but in that of cooling, as also in the squares and backs before the fermentation is begun. Whenever this change, however, takes place, the commixture throws up the gluten and moss to the surface of the liquid in a black scum, which is to be skimmed off, so that the proper yeast may not be soiled with it. It occasions the separation of much of the vegetable slime, or mucilage, called by the German brewers *pech* (pitch).

On the Clarifying or Clearing of Beers.—Clarifiers act either chemically—by being soluble in the beer, and by forming an insoluble compound with the vegetable gluten, and other viscid vegetable extracts; gelatine and albumen, under one shape or other have been most used; the former for beer, the latter, as white of egg, for wine—or mechanically, by being diffused in fine particles through the turbid liquor, and, in their precipitation, carrying down with them the floating vegetable matters. To this class belong sand, bone-black (in some measure, but not entirely), and other such articles. The latter means are very imperfect, and can take down only such matters as exist already in an insoluble state; of the former class, milk, blood, glue, calf's-foot jelly, hartshorn-shavings, and isinglass, have been chiefly recommended. Calve's-foot jelly is much used in many parts of Germany, where veal forms so common a kind of butcher-meat; but in summer it is apt to acquire a putrid taint, and to impart the same to the beer. In these islands, isinglass swollen and partly dissolved in vinegar, or sour beer, is almost the sole clarifier, called finings, employed. It is costly, when the best article is used; but an inferior kind of isinglass is imported for the brewers. The solvent or medium through or with which it is administered is eminently injudicious, as it never fails to infect the beer with an acetous ferment. In Germany their tart wine has been used hitherto for dissolving the isinglass; and this has also the same bad property. Mr. Zimmermann professes to have discovered an unexceptionable solvent in tartaric acid, one pound of which dissolved in 24 quarts of water is capable of dissolving two pounds of ordinary isinglass; forming finings which may be afterward diluted with pure water at pleasure. Such isinglass imported from Petersburg into Berlin costs there only 3*s*. per lb. These finings are best added, as already mentioned, to the worts prior to fermentation, as soon as they are let in to the setting-back or tun, immediately after adding the yeast to it. They are best administered by mixing them in a small tub with thrice their volume of wort, raising the mixture into a froth with a whisk (*twig-besom*, in German), and then stirring it into the worts. The clarification becomes manifest in the course of a few hours, and when the fermentation is completed, the beer will be as brilliant as can be wished; the test of which with the German topers is when they can read a newspaper while a tall glass beaker of beer is placed between the paper and the candle. One quart of finings of the above strength will be generally found adequate to the clearing of 100 gallons of well-brewed lager-beer, though it will be surer to use double that proportion of finings. The Carageen moss, as finings, is to be cut in fine shreds, thrown into the boiling thin wort, when the flocks begin to separate, and before adding the hops; after which the boiling is continued for an hour and a half or two hours, as need be. The clarifying with this kind of finings takes place in the cooler, so that a limpid wort may be drawn off into the fermenting back.

Berlin White or Pale Beer (*Weiss-bier*).—This is the truly patriotic beverage of Prussia Proper, and he is not deemed a friend to his *Vaterland* who does not swig it. It is brewed from 1 part of barley-malt and 5 parts of wheat-malt, mingled, moistened, and coarsely crushed between rollers. This mixture is worked up first with water at 95° Fahr., in the proportion of 30 quarts per *scheffel* of the malt, to which pasty mixture 70 quarts of boiling water are forthwith added, and the whole is mashed in the tun. After it has been left here a little to settle, a portion of the thin liquor is drawn off by the tap, transferred to the copper, and then for each bushel of malt there is added to it a decoction of half a pound of *Altmark* hops separately prepared. This hopped wort, after half an hour's boiling, is turned back with the hops into the mash-tun, of which the temperature should now be 162½° Fahr., but not more. In half an hour the wort is to be drawn off from the grains, and pumped into the cooler. The grains are afterward mashed with from 40 to 50 quarts of boiling water per *scheffel* of malt, and this infusion is drawn off and added to the former worts. The whole mixture is set at 66° Fahr., with a due proportion of top yeast or ordinary barm, and very moderately fermented. According to Zimmermann, a very competent judge, this his native beer is very apt to turn sour, and therefore it must be very speedily consumed. This proneness to acetification is the character of all wheat-malt beers. He recommends, what he himself has made for many years, a substitution of potato-starch sugar for this sort of malt, and as much tartaric acid as to give the degree of tartness peculiar to the pale Berlin beer, even in its best state. This acid moreover prevents the beer from running into the acetous fermentation.

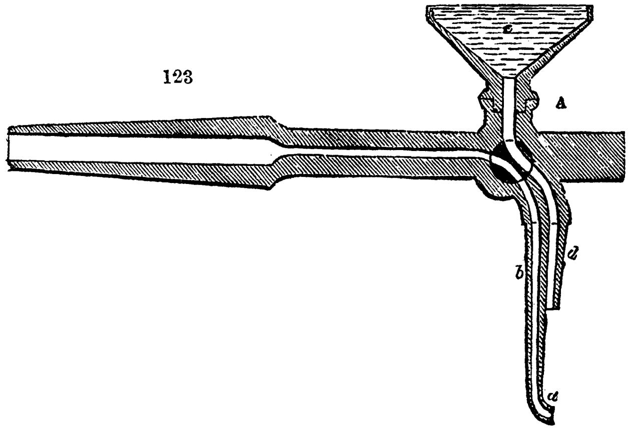
Potato-Beer.—The potatoes being well washed are to be rubbed down to a pulp by such a grating cylinder-machine as is represented in *fig.* 122, where *a* is the hopper for receiving the roots (whether potato or beet, as in the French sugar-factories; *b* is the crushing and grinding-drum; *c*, the handle for turning the spur-wheel *d*, which drives the pinion *e*, and the fly-wheel *f*; *g*, *h*, is the frame. The dotted lines above *c*, are the

122



cullender through which the pulp passes. *Fig.* 123 is the stopcock used in Bavaria for bottling beer. For every scheffel of potatoes 80 quarts of water are to be put with them into the copper, and made to boil.

123



Crushed malt, to the amount of 12 scheffels, is to be well worked about in the mash tun with 360 quarts, or 90 gallons (English) of cold water, to a thick pap, and then 840 additional quarts, or about 6 barrels (English) of cold water are to be successively introduced with constant stirring, and left to stand an hour at rest.

The potatoes having been meanwhile boiled to a fine starch paste, the whole malt-mash, thin and thick, is to be speedily laded into the copper, and the mixture in it is to be well stirred for an hour, taking care to keep the temperature at from 144° to 156° Fahr. all the time, in order that the *diastase* of the malt may convert the starch present in the two substances into sugar and dextrine. This transformation is made manifest by the white pasty liquid becoming transparent and thin. Whenever this happens the fire is to be raised, to make the mash boil, and to keep it at this heat for 10 minutes. The fire is then withdrawn, the contents of the copper are to be transferred into the mash, worked well there, and left to settle for half an hour; during which time the copper is to be washed out, and quickly charged once more with boiling water.

The clear wort is to be drawn off from the top of the tun, as usual, and boiled as soon as possible with the due proportion of hops; and the boiling water may be added in any desired quantity to the drained mash, for the second mashing. Wort made in this way is said to have no flavor whatever of the potato, and to clarify more easily than malt-wort, from its containing a smaller proportion of gluten relatively to that of saccharum.

A scheffel of good mealy potatoes affords from 26 to 27½ lbs. of thick, well-boiled syrup, of the density of 36° Baumé (see AREOMETER); and 26 lbs. of such syrup are equivalent to a scheffel of malt in saccharine strength. Zimmermann thinks beer so brewed from potatoes quite equal, at least, if not superior, to pure malt beer, both in appearance and quality.

Professor Leo, of Munich, has given the following analysis of two kinds of Munich beer:—

	Bock-bier.	Heiliger Vater.
Specific gravity - - -	1·020	1·030
Alcohol - - - - - -	4·000	5·000
Extract - - - - - -	8·200	13·500
Carbonic acid - - - -	0·085	0·077
Water - - - - - - -	87·393	81·923
	100·000	100·000

Carl states the alcohol in the Bavarian beer of Bamberg at only 2·840 in 100. Extract, 6·349.

The following analyses of other German beers are also by Leo:—

	Lichtenhain.	Upper Weimar.	Ilmenau.	Jena.	Double Jena.
Alcohol - - - - -	3·168	2·567	3·096	3·018	2·080
Albumen - - - -	0·048	0·020	0·079	0·045	0·028
Extract - - - - -	4·485	7·316	7·072	6·144	7·153
Water - - - - -	92·299	90·097	89·753	90·793	90·739
	100·000	100·000	100·000	100·000	100·000

Under the term extract, in these analyses, is meant a mixture of starch, sugar, dextrine, lactic acid, various salts, certain extractive and aromatic parts of the hop, gluten, and fatty matter.

The following statement is from some of the published analyses of other beers:—

	Alcohol.
English ale - - - - - - -	8·5 in 100
Burton - - - - - - - -	6·2
Scotch - - - - - - - -	5·8
Common London ale - - - - -	5·0
Brown stout - - - - - -	5·0
London porter - - - - - -	4·0

To the above I add the following analyses of certain ales made lately by myself, as follows:—

1. After exposing a portion of the liquor in a wine glass till the bubbles of carbonic acid were disengaged, I took the specific gravity in a globe with a capillary bored stopper.

2. I then saturated 5000 grain measures of the ale with a test solution of pure carbonate of soda, to determine the quantity of acid present, after which I added an excess of the alkali to precipitate the gluten; which, however, being but small in amount, I did not separate by a filter, dry, and weigh.

3. I subjected the supersaturated liquid to distillation, by the heat of 230° F. in a chlor-zinc bath till I drew off all its alcohol, of which I noted the quantity in water-grain measures and the specific gravity.

4. I evaporated to dryness 500 water-grain measures slowly in a porcelain capsule, to determine the extract.

	Bavarian.	Do. Bock.	Allsop's.	Bass's.
Specific gravity - - - - - -	1·004	1·013	1·010	1·006
Alcohol - - - - - - - - - -	4·00	4·50	6·00	7·00
Extract - - - - - - - - - -	4·50	6·40	5·00	4·80
Acetic acid - - - - - - - -	0·20	0·20	0·20	0·18
Water- - - - - - - - - - -	91·30	88·90	88·80	88·02
	100·00	100·00	100·00	100.00

The Bavarian beers had been recently imported from Germany in casks lined with pitch. The two samples of English ale are those made chiefly for the Indian market, but, being highly hopped, and comparatively clean, as the brewers say, have been recommended as a tonic beverage by the faculty. Hodgson's bitter beer was the original of this quality.

The above Bavarian beers afford no precipitate of gluten with carbonate of potash; the two English ales become mottled thereby, and yield a small portion of gluten, which had been held in solution by the acid, which is here estimated as the acetic. Common vinegar, excise strength, contains 5 per cent. of such acid as is stated in the above analysis, indicating from 3 to 4 per cent. of table vinegar in the above varieties of beer.

Ale, pale or bitter; *brewed chiefly for the Indian market and for other tropical countries.*—It is a light beverage, with much aroma, and, in consequence of the regulations regarding the malt duty, is commonly brewed from a wort of specific gravity 1·055 or upwards; for no drawback is allowed by the excise on the exportation of beer brewed from worts of a lower gravity than 1·054. This impolitic interference with the operations of trade compels the manufacturer of bitter beer to employ wort of a much greater density than he otherwise would do; for beer made from wort of the specific gravity 1·042 is not only better calculated to resist secondary fermentation and the other effects of a hot climate, but is also more pleasant and salubrious to the consumer. Under present circumstances the law expects the brewer of bitter beer to obtain 4 barrels of marketable beer from every quarter of malt he uses, which is just barely possible when the best malt of a good barley year is employed. With every quarter of such malt 16 lbs of the best hops are used; so that, if we assume the cost of malt at 60*s*. per quarter, and the best hops at 2*s*. per lb., we shall have, for the prime cost of each barrel of bitter beer, in malt 15*s*., in hops 8*s*., and together 23*s*.; from which, on exportation, we must deduct the drawback of 5*s*. per barrel allowed by the excise, which brings the prime cost down to 18*s*. per barrel, exclusive of the expense of manufacture, wear and tear of apparatus, capital invested in barrels, cooperage, &c., which constitute altogether a very formidable outlay. As, however, this ale is sold as high as from 50*s*. to 65*s*. per barrel, there can be no doubt that the bitter ale trade has long been, and still continues, an exceedingly profitable speculation, though somewhat hazardous, from the liability of the article to undergo decomposition ere it finds a market.

The English ale-bibbers were recently horrified by a public report, apparently well authenticated, that French chemistry was largely engaged in preparing immense quantities of that most deadly poison *strychnine*, for the purpose of drugging the pale bitter ale, in such great vogue at present in Great Britain and its colonies. The fable would have been made more *piquant*, by suggesting that it was a project of the Prince President of France to indemnify his country for the miseries of Waterloo. It is surprising that such a tale should have been told by any gossip, and almost incredible that it should have been entertained gravely by any chemist of reputation, for the following plain reasons: 1. Strychnine is an exceedingly costly article; 2. It has a most unpleasant metallic bitter taste; 3. It is a notorious poison, and by its use in any brewery would ruin the reputation of the brewer; 4. It cannot be introduced into ordinary beer brewed with hops, because it is entirely precipitated by infusions of that wholesome fragrant herb. In fact, the quercitannic acid of hops is incompatible with strychnia and all its kindred alkaloids. Hence hopped beer becomes in this respect a sanatory beverage; refusing to take up a particle of strychnia, and other noxious drugs of like character. Had the two chemists employed by Messrs. Allsopp to disprove the above calumny in respect to their bitter ale taken the trouble to consult Berzelius, Anthony Todd Thompson, and other writers on strychnia, they might have saved themselves the vain attempt to dissolve strychnia in the said beer for it all remains at the bottom in combination with the quercitannic acid so abundantly present. Were the *nux vomica* powder, from which strychnia is extracted,

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even stealthily thrown into the mash tun, its dangerous principle would be all infallibly thrown down with the grounds in the subsequent hop-boil.

The Board of Excise or Inland Revenue having a few years ago, with delusive liberality, permitted the legislature to grant leave to use sugar in the place of barley malt in breweries, an extensive sugar merchant in London, hoping, under this pretended boon, to acquire a new and wealthy class of customers, employed me to ascertain by experiment the relative values of malt and sugar for the manufacture of beer. Ten samples of muscovado sugar of several qualities were examined, and were found to vary very slightly in the proportions of alcohol they could furnish by fermentation in a brewer's tun; the average being 12 gallons of proof spirit for 112 lbs. of the sugar; whereas an equal quantity of proof spirit could be obtained from 4·8 bushels of malt. One pound of malt yields ¾ of a lb of extract, capable of making as much beer as that weight of sugar. On comparing the actual prices of sugar and malt, we shall see how ruinous a business it would be to use sugar instead of malt in a brewery, and hence the delusiveness of the excise generosity towards the beer trade.

BEET-ROOT SUGAR. See Sugar.

BELL METAL, an alloy of copper and tin. See Copper

BELLOWS. See Metallurgy.

BEN OIL. See Oil of Ben.

BENGAL STRIPES. Ginghams; a kind of cotton cloth woven with colored stripes.

BENJAMIN or BENZOIN. (*Benjoin*, Fr.; *Benzöe*, Germ.) A species of resin used chiefly in perfumery. It is extracted by incision from the trunk and branches of the *styrax benzoin*, which grows in Java, Sumatra, Santa Fé, and in the kingdom of Siam. The plant belongs to the decandria monogynia of Linnæus, and the natural family of the ebenaceæ. It hardens readily in the air, and comes to us in brittle masses, whose fracture presents a mixture of red, brown, and white grains of various sizes, which, when white, and of a certain shape, have been called *amygdaloid*, from their resemblance to almonds. The *sorted* benzoin is, on the other hand, very impure.

The fracture of benzoin is conchoidal, and its lustre greasy: its specific gravity varies from 1·063 to 1·092. It has an agreeable smell, somewhat like vanilla, which is most manifest when it is ground. It enters into fusion at a gentle heat, and then exhales a white smoke, which may be condensed into the acicular crystals of benzoic acid, of which it contains 18 parts in the hundred. Stoltze recommends the following process for extracting the acid: The resin is to be dissolved in 3 parts of alcohol, the solution is to be introduced into a retort, and a solution of carbonate of soda dissolved in dilute alcohol is to be gradually added to it, till the free acid be neutralized; and then a bulk of water equal to double the weight of the benzoin is to be poured in. The alcohol being drawn off by distillation, the remaining liquor contains the acid, and the resin floating upon it may be skimmed off and washed, when its weight will be found to amount to about 80 per cent. of the raw material. The benzoin contains traces of a volatile oil, and a substance soluble in water, at least through the agency of carbonate of potash. Ether does not dissolve benzoin completely. The fat and volatile oils dissolve very little of it.

Unverdorben has found in benzoin, besides benzoic acid, and a little volatile oil, no less than three different kinds of resin, none of which has, however, been turned as yet to any use in the arts.

Benzoin is of great use in perfumery, as it enters into a number of preparations; among which may be mentioned fumigating pastilles, fumigating cloves (called also nails), *poudre à la marechale*, &c. The alcoholic tincture, mixed with water, forms *virginal* milk. Benzoin enters also into the composition of certain varnishes employed for snuff-boxes and walking-sticks, in order to give these objects an agreeable smell when they become heated in the hand. It is likewise added to the spirituous solution of isinglass, with which the best court-plaster is made.

BERLIN BLUE. Prussian blue, which see.

BERRIES OF AVIGNON, *and Persian Berries.* (*Graines d' Avignon*, Fr.; *Gelbbeeren*, Germ.) A yellowish dye-drug, the fruit of the *rhamnus infectorius*, a plant cultivated in Provence, Languedoc, and Dauphiné, for the sake of its berries, which are plucked before they are ripe, while they have a greenish hue. Another variety comes from Persia, whence its trivial name: it is larger than the French kind, and has superior properties. The principal substances contained in these berries are: 1. A coloring matter, which is united with a matter insoluble in ether, little soluble in concentrated alcohol, and very soluble in water: it appears to be volatile. 2. A matter remarkable for its bitterness, which is soluble in water and alcohol. 3. A third principle in small quantity. A decoction of one part of the Avignon or Persian berry in ten of water affords a brown-yellow liquor, bordering upon green, having the smell of a vegetable extract, and a slightly bitter taste.

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With gelatine the decoction gives, after some time,	a slight precipitate,—
— alkalis	a yellow hue,
— acids	a slight muddiness,
— lime-water	a greenish-yellow tint,
— alum	a yellow color,
— red sulphate of iron	an olive-green color,
— sulphate of copper,	an olive color,
— proto-muriate of tin	a greenish yellow with a slight precipitate. (See Calico Printing).

BERYL. A beautiful mineral or gem, of moderate price, usually of a green color of various shades, passing into honey-yellow and sky blue.

BEZOAR. The name of certain concretions found in the stomachs of animals, to which many fanciful virtues were formerly ascribed. They are interesting only to the chemical pathologist.

BICARBONATE OF POTASH AND OF SODA. These salts, so much used in medicine, may, according to M. Behrens, be very readily prepared by gradually adding acetic acid to a strong solution of their carbonates; that of soda being hot. The carbonic acid, at the moment of its disengagement, by the stronger affinity of the acetic for the alkalis, combines with a portion of them to form bicarbonates, which fall to the bottom of the vessel in which the mixture is made. The supernatant acetate being separated by decantation, the residuary bicarbonate is to be pressed in linen washed with ice-cold water, and dried. This process may be practised by the chamber chemist, but will not afford the bicarbonates at so cheap a rate as the ordinary modes of manufacture. But a far better method of forming these two salts is by exposing each of them in chambers on extensive surfaces, perforated with small holes, to an atmosphere of carbonic acid, generated by the combustion of coke, and purified by being passed through cold water, by the action of an air-pump worked by a steam-engine.

BILE. (*Bile*, Fr.; *Galle*, Germ.) The secreted liquor of the liver in animals. For an account of the uses of animal bile in the arts, see Gall.

Bile (ox's) is composed, according to Berzelius,

1.	Of biline, fellinic acid, and fat of gall	8·00
2.	Mucus	0·30
3.	Of alkali combined with biline, &c.	0·41
4.	Muriate of soda, extractive matter	0·74
5.	Phosphate of soda: do. of lime, &c.	0.11
6.	Water	90·44
		100·00

Thenard's analysis gives:—

1.	Resin of bile and picromel (acid gallenate of soda)	10·54
2.	Coloring matter	0·50
3.	Soda	0·50
4.	Phosphate of soda	0·25
5.	Muriate of soda	0·40
6.	Sulphate of soda	0·10
7.	——— of lime	0·15
8.	Traces of oxide of iron	—
9.	Water	87·56
		100·00

A substance may be tested for bile by dropping into it two-thirds of its bulk of oil of vitriol very slowly, so that the heat does not exceed 122° Fahr., adding a few drops of syrup, and shaking the mixture; when it should assume a deep violet hue.

BIRDLIME. (*Glu*, Fr.; *Vogelleim*, Germ.) The best birdlime may be made from the middle bark of the holly, boiled seven or eight hours in water, till it is soft and tender, then laid by heaps in pits under ground, covered with stones after the water is drained from it. There it must be left during two or three weeks, to ferment in the summer season, and watered, if necessary, till it passes into a mucilaginous state. It is then to be pounded in a mortar to a paste, washed in running water, and kneaded till it be free from extraneous matters. It is next left for four or five days in earthen vessels to ferment and purify itself, when it is fit for use. Birdlime may be made by the same process from the mistletoe (*viburnum lantana*), young shoots of elder, and the barks of other vegetables, as well as from most parasite plants.

Good birdlime is of a greenish color, and sour flavor, somewhat resembling that of linseed oil; gluey, stringy, and tenacious. By drying in the air it becomes brittle and may be powdered; but its viscosity may be restored by moistening it. It has an acid reaction with litmus paper. It contains resin, mucilage, a little free acid, coloring and extractive matter. The resin has been called Viscine.

All the parts of the mistletoe contain a peculiar viscid gluey substance, which they yield by decoction, particularly of the bark and green portions; as also from the expressed juice of the bark or berries, when it is kneaded with the fingers under water. The birdlime is thus obtained in the form of a white opaque mass, sticking to the fingers. It may also be extracted from the berries of the mistletoe by means of ether, repeatedly applied, digested with them. It dissolves at first a mixture of green wax and birdlime, but afterwards birdlime alone. By distilling off the ether, the birdlime remains colorless and pure. Birdlime may be considered as a kind of viscid resin which does not dry, and resembling in this respect an ointment of oil or lard and rosin melted together—the old *basilicon* of the surgeon. Alcohol, even boiling hot, dissolves hardly any birdlime; but merely its waxy impurities, which it deposits in flocks on cooling. It is soluble in the oils of rosemary and turpentine, as also in petroleum. Heated with the ley of caustic potash, it forms a compound soluble in alcohol. Nitric acid converts it into oxalic acid, and into a fat which solidifies.

Macaire has examined a substance which exudes from the receptacle and involucre of the *atractylis gummifera*, and describes it as the pure matter of birdlime, which he styles *viscine*. It is said to be composed in 100 parts of 75·6 carbon, 9·2 hydrogen, and 15·2 oxygen. Common birdlime may be regarded as a mixture of viscine, vegetable mucilage, and vinegar. The young shoots of the *ficus elastica* afford a milky juice, which is viscine, while the old branches afford a juice rich in caoutchouc.

BISCUITS. For the following account of the mechanical system of baking biscuits for the royal navy, I am indebted to the ingenious inventor, Thomas Grant, Esq.

Ships' biscuits are now made by machinery; and one of the reasons for this has been that the manual preparation of them was too slow and too costly during the last war. A landsman knows very little of the true value of a biscuit: with a seaman, biscuit is the only bread that he eats for months together. There are many reasons why common loaves of bread could not be used during a long voyage; because, containing a fermenting principle, they would soon become musty and unfit for food, if made previous to the voyage; while the preparation of them on board ship is subject to insuperable objections. Biscuits contain no leaven, and, when well baked throughout, they suffer little change during a long voyage.

The allowance of biscuit to each seaman on board a queen's ship is a pound per day (averaging six biscuits to the pound). The supply of a man-of-war for several months is, consequently, very large; and it often happened during the last war that the difficulty of making biscuits fast enough was so great, that at Portsmouth wagon loads were unpacked in the streets and conveyed on board ships.

We shall now describe the mode of making biscuits by hand; and afterwards speak of the improved method. The bakehouse at Gosport contained nine ovens, and to each was attached a gang of five men—the "turner," the "mate," the "driver," the "breakman," and the "idleman." The requisite proportions of flour and water were put into a large trough, and the "driver," with his naked arms, mixed the whole up together into the form of dough—a very laborious operation. The dough was then taken from the trough and put on a wooden platform called the break: on this platform worked a lever called the break-staff, five or six inches in diameter, and seven feet long; one end of this was loosely attached by a kind of staple to the wall, and the breakman, riding or sitting on the other end, worked this lever to and fro over the dough, by an uncouth jumping or shuffling movement. When the dough had become kneaded by this barbarous method into a thin sheet, it was removed to the moulding-board, and cut into slips by means of an enormous knife; these slips were then broken into pieces, each large enough for one biscuit, and then worked into a circular form by the hand. As each biscuit was shaped it was handed to a second workman, who stamped the king's mark, the number of the oven, &c., on the biscuit. The biscuit was then docked, that is, pierced with holes by an instrument adapted to the purpose. The finishing part of the process was one in which remarkable dexterity was displayed. A man stood before the open door of the oven, having in his hand the handle of a long shovel called a peel, the other end of which was lying flat in the oven. Another man took the biscuits as fast as they were formed and stamped, and jerked or threw them into the oven with such undeviating accuracy that they should always fall on the peel. The man with the peel then arranged the biscuits side by side over the whole floor of the oven. Nothing could exceed (in manual labor alone) the regularity with which this was all done. Seventy biscuits were thrown into the oven and regularly arranged in one minute; the attention of each man being vigorously directed to his own department; for a delay of a single second on the part of any one man would have disturbed the whole gang. The biscuits do not require many minutes baking; and as the oven is kept open during the time that it is being filled, the biscuits first thrown in would be overbaked were not some precaution taken to prevent it. The moulder therefore made those which were to be first thrown into the oven larger than the subsequent ones, and diminished the size by a nice gradation.

The mode in which, since about the year 1831, ships' biscuits have been made by machinery invented by T. T. Grant, Esq., of the Royal Clarence yard, is this: the meal or flour is conveyed into a hollow cylinder four or five feet long and about three feet in diameter, and the water, the quantity of which is regulated by a gauge admitted to it; a shaft, armed with long knifes, works rapidly round in the cylinder, with such astonishing effect that, in the short space of three minutes, 340 pounds of dough are produced, infinitely better made than that mixed by the naked arms of a man. The dough is removed from the cylinder and placed under the breaking-rollers; these latter, which perform the office of kneading, are two in number, and weigh 15 cwt. each; they are rolled to and fro over the surface of the dough by means of machinery, and in five minutes the dough is perfectly kneaded. The sheet of dough, which is about two inches thick, is then cut into pieces half a yard square, which pass under a second set of rollers, by which each piece is extended to the size of six feet by. three, and reduced to the proper thickness for biscuits. The sheet of dough is now to be cut up into biscuits, and no part of the operation is more beautiful than the mode by which this is accomplished. The dough is brought under a stamping or cutting-out press, similar in effect, but not in detail, to that by which circular pieces for coins are cut out of a sheet of metal. A series of sharp knives are so arranged that, by one movement, they cut out of a piece of dough a yard square about sixty hexagonal biscuits. The reason for a hexagonal (six-sided) shape is, that not a particle of waste is thereby occasioned, as the sides of the hexagonals accurately fit into those of the adjoining biscuits; whereas circular pieces cut out of a large surface always leave vacant spaces between. That a flat sheet can be divided into hexagonal pieces without any waste of material is obvious.

Each biscuit is stamped with the queen's mark, as well as punctured with holes by the same movement which cuts it out of the piece of dough. The hexagonal cutters do not sever the biscuits completely asunder; so that a whole sheet of them can be put into the oven at once on a large peel or shovel adapted for the purpose. About fifteen minutes are sufficient to bake them; they are then withdrawn and broken asunder by the hand.

The corn for the biscuits is purchased at the markets, and cleaned, ground, and dressed; at the government mills; in quality it is a mixture of fine flour and middlings, the bran and pollard being removed. The ovens for baking are formed of fire-brick and tile, with an area of about 160 feet. About 112 lbs. weight of biscuits are put into the ovens at once. This is called a suit, and is reduced to about 110 lbs. by the baking. From twelve to sixteen suits can be baked in each oven every day, or after the rate of 224 lbs. per hour. The men engaged are dressed in clean check shirts and white linen trowsers, apron, and cap; and every endeavor is made to observe the most scrupulous cleanliness.

We may now make a few remarks on the comparative merits of the hand and the machine processes. If the meal and the water with which the biscuits are made be not thoroughly mixed up, there will be some parts moister than others. Now, it was formerly found that the dough was not well mixed by the arms of the workman; the consequence of which was that the dry parts became burnt up, or else that the moist parts acquired a peculiar kind of hardness which the sailors called "flint:" these defects are now removed by the thorough mixing and kneading which the ingredients receive by the machine.

We have seen that 450 lbs. of dough may be mixed by the machine in four minutes, and kneaded in five or six minutes; we need hardly say how much quicker this is than men's hands could effect it. The biscuits are cut out and stamped sixty at a time, instead of singly: besides the time thus saved, the biscuits become more equally baked, by the oven being more speedily filled. The nine ovens at Gosport used to employ 45 men to produce about 1,500 lbs. of biscuit per hour; 16 men and boys will now produce, by the same number of ovens, 2,240 lbs. of biscuits (one ton) per hour.

The comparative expense is thus stated: Under the old system, wages, and wear and tear of utensils, cost about 1*s*. 6*d*. per cwt. of biscuit: under the new system, the cost is 5*d*.

The bakehouses at Deptford, Gosport, and Plymouth, could produce 7,000 or 8,000 tons of biscuits annually, at a saving of 12,000*l*. per annum from the cost under the old system. The advantages of machine-made over hand-made biscuits, therefore, are many: quality, cleanliness, expedition, cheapness, and independence of government contractors.

Fig. 124 represents the biscuit machinery, as executed beautifully by Messrs. Rennie, engineers. *a*, is the breaking roller, table and roller; *b*, the finishing roller, table and roller; *c*, *c*, docking machines for stamping out the biscuits; *d*, mixing machine for making the dough; *e*, spur pinion to engine shaft; *f*, spur wheel; *g*, *g*, bevel mitre-wheels to give the upright motion; *h*, *h*, bevel-wheels for working the mixing machine; *i*, *i*, *i*, ditto for communicating motion to the rolling machines; *j*, *j*, *k*, the crank shaft; *l*, *l*, connecting rods; *m*, *m*, pendulums for giving motion to rollers; *n*, *n*, clutches for connecting either half of the machinery to the other.

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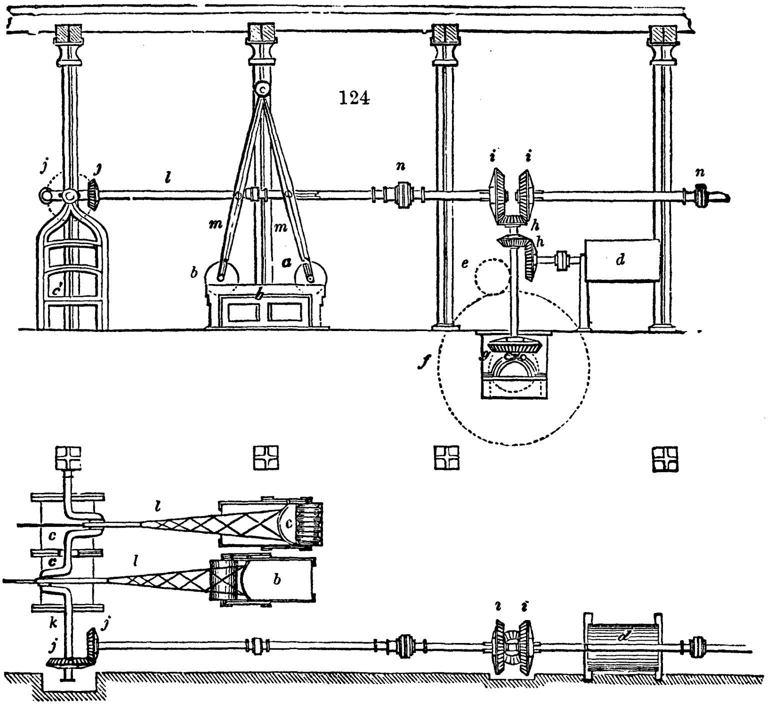

BISMUTH. (*Bismuth*, Fr.; *Wismuth*, Germ.) Called also marcasite and tin-glass. It was shown to be a metal somewhat different from lead, by G. Agricola, in 1546; Stahl and Dufay proved its peculiarity; but it was more minutely distinguished by Pott and Geoffroy about the middle of the last century. It is a rare substance, occurring native, as an oxide, under the name of bismuth ochre; as a sulphuret, called bismuth glance; as a sulphuret with copper, called copper bismuth ore; as also with copper and lead, called needle ore. It is found associated likewise with selenium and tellurium. The native metal occurs in various forms and colors, as white, reddish, and variegated; in primitive and floetz formations, along with the ores of cobalt, nickel, copper, silver and bismuth ochre; at the Saxon Erzegebirge, near Schneeberg, and Joh. Georgenstadt; also in Bohemia, Baden, Wurtemberg, Hessia, Sweden, Norway, England, and France.

The production of this metal is but a limited object of the smelting-works, of the Saxon Erzegebirge at Schneeberg. It there occurs, mixed with cobalt speiss, in the proportion of about 7 per cent. upon the average, and is procured by means of a peculiar furnace of liquation, which is the most economical method, both as to saving fuel, and oxidizement of the bismuth.

The bismuth eliquation furnace at Schneeberg is represented in *figs.* 125, 126, and 127, of which the first is a view from above, the second a view in front, and the third a transverse section in the dotted line A B of *fig.* 125. *a*, is the ash-pit; *b*, the fire-place; *c*, the eliquation pipes; *d*, the grate of masonry or brickwork, upon which the fuel is thrown through the fire-door *e e*. The anterior deeper lying orifice of the eliquation pipes is closed with the clay-plate *f*; which has beneath a small circular groove, through which the liquefied metal flows off. *g* is a wall extending from the hearth-sole nearly to the anterior orifices of the liquation pipes, in which wall there are as many fire-holes, *h*, as there are pipes in the furnace: *i* are iron pans, which receive the fluid metal; *h*, a wooden water trough, in which the bismuth is granulated and cooled; *l*, the posterior and higher lying apertures of the eliquation pipes, shut merely with a sheet-iron cover. The granulations of bismuth drained from the posterior openings fall upon the flat surfaces *m*, and then into the water-trough. *n n* are draught-holes in the vault between the two pipes, which serve for increasing or diminishing the heat at pleasure.

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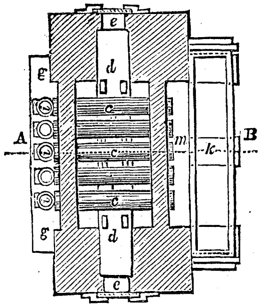

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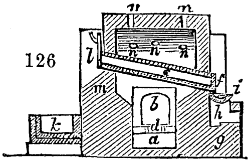

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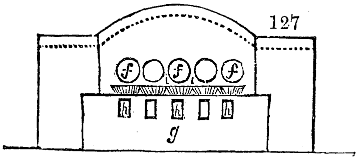

The ores to be eliquated (sweated) are sorted by hand from the gangue, broken into pieces about the size of a hazel nut, and introduced into the ignited pipes; one charge consisting of about ½ cwt.; so that the pipes are filled to half their diameter, and three fourths of their length. The sheet-iron door is shut, and the fire strongly urged, whereby the bismuth begins to flow in ten minutes, and falls through the holes in the clay-plates into hot pans containing some coal-dust. Whenever it runs slowly, the ore is stirred round in the pipes, at intervals during half an hour, in which time the liquation is usually finished. The residuum, called bismuth barley (*graupen*), is scooped out with iron rakes into a water trough; the pipes are charged afresh; the pans, when full, have their contents cast into moulds, forming bars of from 25 to 50 pounds weight. About 20 cwt. of ore are smelted in 8 hours, with a consumption of 63 Leipzic cubic feet of wood. The total production of Shneeberg, in 1830, was 9800 lbs. The bismuth thus procured by liquation upon the great scale, contains no small admixture of arsenic, iron, and some other metals, from which it may be freed by solution in nitric acid, precipitation by water, and reduction of the subnitrated oxyde by black flux. By exposing the crude bismuth for some time to a dull red heat, under charcoal, arsenic is expelled.

Bismuth is white, and resembles antimony, but has a reddish tint; whereas the latter metal has a blueish cast. It is brilliant, crystallizes readily in small cubical facets, is very brittle, and may be easily reduced to powder. Its specific gravity is 9·83; and by hammering it with care, the density may be increased to 9·8827. It melts at 480° Fahr., and may be cooled 6 or 7 degrees below this point without fixing; but the moment it begins to solidify, the temperature rises to 480°, and continues stationary till the whole mass is congealed. When heated from 32° to 212°, it expands $\frac{1}{710}$ in length. When pure it affords a very valuable means of adjusting the scale of high-ranged thermometers. At strong heats bismuth volatilizes, may be distilled in close vessels, and is thus obtained in crystalline laminæ.

The alloy of bismuth and lead in equal parts has a density of 10·709, being greater than the mean of the constituents; it has a foliated texture, is brittle, and of the same color as bismuth. Bismuth, with tin, forms a compound more elastic and sonorous than the tin itself, and is therefore frequently added to it by the pewterers. With 1 of bismuth and 24 of tin, the alloy is somewhat malleable; with more bismuth, it is brittle. When much bismuth is present, it may be easily parted by strong muriatic acid, which dissolves the tin, and leaves the bismuth in a black powder. It has been said, that an alloy of tin, bismuth, nickel, and silver hinders iron from rusting. (*Erdmann's Journal.*) The alloy of bismuth with tin and lead was first examined by Sir I. Newton, and has been called ever since fusible metal. Eight parts of bismuth, 5 of lead, and 3 of tin, melt at the moderate temperature of 202° F.; but 2 of bismuth, 1 of lead, and 1 of tin, melt at 200·75° F. according to Rose. A small addition of mercury of course aids the fusibility. Such alloys serve to take casts of anatomical preparations. An alloy of 1 bismuth, 2 tin, and 1 lead, is employed as a soft solder by the pewterers; and the same has been proposed as a bath for tempering steel instruments. Cake-moulds, for the manufacturers of toilet soaps, are made of the same metal; as also excellent clichés for stereotype, of 3 lead, 2 tin, and 5 bismuth; an alloy which melts at 199° F. This compound should be allowed to cool upon a piece of pasteboard, till it becomes of a doughy consistence, before it is applied to the mould, to receive the impress of the stamp.

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The employment of plates of fusible metal as safety *rondelles*, to apertures in the tops of steam boilers, has been proposed in France, because they would melt and give way at elevations of temperature under those which would endanger the bursting of the vessel; the fusibility of the alloy being proportioned to the quality of steam required for the engine. It has been found, however, that boilers, apparently secured in this way, burst, while the safety discs remained entire; the expansive force of the steam causing explosion so suddenly, that the fusible alloy had not time to melt or give way.

There are two, perhaps three, oxydes of bismuth; the first and the third, or the sub-oxyde and super-oxyde, are merely objects of chemical curiosity. The oxyde proper occurs native, and may be readily formed by exposing the metal to a red-white heat in a muffle, when it takes fire, burns with a faint blue flame, and sends off fumes which condense into a yellow pulverulent oxyde. But an easier process than that now mentioned is to dissolve the bismuth in nitric acid, precipitate with water, and expose the precipitate to a red heat. The oxyde thus obtained has a straw yellow color, and fuses at a high heat into an opaque glass of a dark-brown or black color; but which becomes less opaque and yellow after it has cooled. Its specific gravity is so high as 8·211. It consists of 89·87 of metal and 10·13 oxygen in 100 parts. The above precipitate, which is a sub-nitrate of bismuth, is called *pearl-white*, and is employed as a flux for certain enamels; as it augments their fusibility without imparting any color to them. Hence, it is used sometimes as a vehicle of the colors of other metallic oxydes. When well washed, it is employed in gilding porcelain; being added in the proportion of one fifteenth to the gold. But pearl-white is most used by ladies as a cosmetic for giving a brilliant tint to a faded complexion. It is called *blanc de fard*, by the French. If it contains, as bismuth often does, a little silver, it becomes gray or dingy colored on exposure to light. When the oxyde is prepared, by dropping the nitric solution into an alkaline ley in excess, if this precipitate is well washed and dried, it forms an excellent medicine; and is given, mixed with gum tragacanth, for the relief of cardialgia, or burning and spasmodic pains of the stomach.

Another sort of pearl-powder is prepared by adding a very dilute solution of common salt to the above nitric solution of bismuth, whereby a pulverulent sub-chloride of the metal is obtained in a light flocculent form. A similar powder of a mother-of-pearl aspect may be formed by dropping dilute muriatic acid into the solution of nitrate of bismuth. The arsenic always present in the bismuth of commerce is converted by nitric acid into arsenic acid, which, forming an insoluble arseniate of bismuth, separates from the solution, unless there be such an excess of nitric acid as to re-dissolve it. Hence the medicinal oxyde, prepared from a rightly-made nitrate, can contain no arsenic. If we write with a pen dipped in that solution, the dry invisible traces will become legible on plunging the paper in water.

It has been proposed to substitute bismuth for lead in assaying silver, as a smaller quantity of it answers the purpose, and, as its oxyde is more fluent, can therefore penetrate the cupel more readily, and give a more rapid result. But, independently of the objection from its high price, bismuth has the disadvantage of boiling up, as well as of *rocking* or vegetating, with the silver, when the cupellation requires a high heat. In extracting the silver from the galena found in the copper-mine of Yahlun, it has happened sometimes that the silver concreted towards the end of the operation, and produced a cauliflower excrescence, which had to be cupelled again with a fresh dose of lead. It was observed that, in this case, a portion of the silver had passed into the cupel. Berzelius detected in a sample of silver thus concreted the presence of bismuth.

The nitrate of bismuth, mixed with solution of tin and tartar, has been employed as a mordant for dyeing lilach and violet in calico printing.

BISTRE. (*Bistre*, Fr.; *bister*, Germ.) A brown color which is used in water colors, in the same way as China ink. It is prepared from wood-soot, that of beech being preferred. The most compact and best burned parcels of soot are collected from the chimney, pulverized, and passed through a silk sieve. This powder is infused in pure water, and stirred frequently with a glass ruler, then allowed to settle, when the water is decanted. If the salts are not all washed away, the process may be repeated with warm water. The paste is now to be poured into a long narrow vessel filled with water, stirred well, and left to settle for a few minutes, in order to let the grosser parts subside. The supernatant part is then to be poured off into a similar vessel. This process may be repeated twice or thrice, to obtain a very good bistre. At last the settled deposite is sufficiently fine, and when freed from its supernatant water, it is mixed with gum-water, moulded into proper cakes, and dried. It is not used in oil painting, but has the same effect in water-colors as brown pink has in oil.

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BITTER PRINCIPLE. (*Amère*, Fr.; *Bitterstoff*, Germ.) This principle has not been insulated hitherto by the chemist from the other proximate principles of plants, but its existence is sufficiently recognized by the taste. The following list contains the principal bitter substances, many of which have been used in the arts and in medicine.

Name.	Part employed.	Country.	Observations.
Quassia	Wood	Surinam, E. Indies	Powerfully bitter
Wormwood	Herb	Great Britain	Ditto
Aloe	Inspissated juice	South Africa	Ditto
Angustura	Bark	South America	Ditto
Orange	Unripe Fruit	South of Europe	Aromatic bitter
Ditto	Peel	Ditto	
Acorus	Root	Ditto	Ditto
Carduus Benedictus	Herb	Greek Archipelago	
Cascarilla	Bark	Jamaica	Ditto
Centaury	Herb	Great Britain	
Camomile	Flowers		
Colocynth	Fruit	Levant	Intolerably bitter
Colombo	Root	East Africa	Very bitter
Fumitory	Herb	Great Britain	
Gentiana lutea	Root	Switzerland	Very bitter
Ground Ivy	Herb	Great Britain	
Walnut	Peels		With tannin
Island moss			With starch
Hops	Scales of the female flowers	Great Britain	Aromatic bitters
Milfoil	Herb flowers	Great Britain	
Large-leaved Satyrion	Herb	Great Britain	
Rhubarb	Root	China	Disagreable odor
Rue	Herb	Great Britain	Bitter and sharp
Tansy	Herb flowers	Ditto	Bitter and offensive
Bitter trefoil	Herb	Ditto	
Simarouba	Bark	Guiana	
Bryony	Root	Great Britain	Sharp, bitter, nauseous
Coffee	Seeds	Arabia	

BITUMEN, or ASPHALTUM. (*Bitume*, Fr.; *Erdpech*, Germ.) A black substance found in the earth, externally not dissimilar to pit-coal. It is composed of carbon, hydrogen, and oxygen, like organic bodies; but its origin is unknown. It has not been observed among the primitive or older strata, but only in the secondary and alluvial formations. It constitutes sometimes considerable beds, as in the Isle of Trinidad, where it occurs over an extensive district, in scattered masses. The greater part of the asphaltum to be met with in commerce comes from the Dead Sea, on whose shores it is cast up and gathered; whence it has got the name of Jewish bitumen. In its black color and fracture it resembles ordinary pitch. By friction it affords negative electricity. Its average density is 1·16. It melts at the temperature of boiling water, kindles very readily at the flame, burns brightly with a thick smoke and leaves little ashes. Distilled by itself, it yields a peculiar bituminous oil, very little water, some combustible gases, and traces of ammonia. It leaves about one-third of its weight of charcoal after combustion, and ashes, containing silica, alumina, oxide of iron, sometimes a little lime, and oxide of manganese. According to John, asphaltum may be decomposed, by different solvents, into three distinct substances. Water dissolves nothing; alcohol (anhydrous) dissolves out a yellow resin equal to 5 per cent. of the weight of the asphaltum; that resin is soluble in dilute alcohol and in ether. The portion not soluble in the alcohol gives up a brown resin to ether, amounting to 70 per cent. of the weight of the asphaltum. On evaporating off the ether, the resin remains of a brownish-black colour, which dissolves readily in the volatile oils and in the oil of petrolium. The portion of asphaltum which does not dissolve in ether is very soluble in oil of turpentine, and in oil of petroleum; but less so in oil of lavender. These three resinous principles dissolve all together by digestion in the oils of anise, rosemary, turpentine, olive, hemp-seed, nut, and linseed. Caustic potash dissolves a notable quantity of asphaltum; but carbonate of potash has no effect upon it.

Asphaltum enters into the composition of hydraulic cements, and into that of black varnishes called japans, for coating iron trays, &c. A similar varnish may be prepared by dissolving 12 parts of fused amber, 2 parts of rosin, and 2 parts of asphaltum, in 6 parts of linseed oil varnish, to which 12 parts of oil of turpentine have been added.

There is a kind of bitumen found at Aniches, in France, in the department of the North, which is black, very fusible and soft. It burns with flame. Alcohol, ether, and oil of turpentine extract from it a fatty substance, which may be saponified with alkalis.

The bitumen of Murindò, near Choco, in Columbia, is of a brownish-black color, soft, and has an earthy fracture. It has an acrid taste, burns with a smell of vanilla, and is said to contain a large quantity of benzoic acid. It appears to be the result of the decomposition of trees containing benzoin.

Asphaltum occurs abundantly at the surface of the salt lake Asphaltites, in Judea, produced from springs in the neighborhood; it is floated down, gathers consistence, and accumulates upon the surface of the lake; the winds drive it on the shores, and the inhabitants collect it for sale. Its inspissation diffuses a disagreable smell in the air of that region, which is supposed by the natives to be powerful enough to kill birds when they attempt to fly across the lake.

But probaby the most remarkable locality of asphaltum in the world is the entire basin or rather plain of it, in the island of Trinidad, called the Tar Lake. It lies on the highest land in the island, and emits a strong smell, sensible at ten miles' distance. Its first appearance is that of a lake of water, but when viewed more nearly it seems to be a surface of glass. In hot weather its surface liquifies to the depth of an inch, and it cannot then be walked upon. It is of a circular form, about three miles in circumference, and of a depth not ascertained. Large fissures frequently open and close up in it, whence the pitch has been supposed to float upon a body of water. The soil for a considerable distance round it, consists of cinders and burnt earth, and presents in many points indications of convulsions by subterranean fire. In several parts of the neighboring woods, there are round holes and fissures in the ground, containing liquid bitumen to the depth of two inches.

Mr. Hatchett examined some specimens from Trinidad, and concluded that what had been heretofore supposed to be a pure mineral pitch was in reality only a porous stone of the argillaceous kind, much impregnated with bitumen.

These various bitumens belong exclusively to the secondary and tertiary geological formations, and are not found among primitive rocks, except very rarely in veins. They occur most generally in calcareous, argillaceous and sandy strata, and also in volcanic districts. Petroleum frequently floats on the waters which issue from the volcanic mountains, or which lie at their base; even the sea is at times covered with it near the volcanic islands of Cape de Verd. Mr. Breislack observed a petroleum spring rising from the bottom of the sea near the south base of Vesuvius.

The substance with which bitumen seems to have the most constant and most remarkable relations is sea-salt; so that almost all the countries most abundant in petroleum, as Italy, Transylvania, Persia, the environs of Babylon, the region of the Dead Sea, &c., contain salt mines, or lakes, or exhibit saline efflorescences. Iron pyrites is often impregnated with petroleum, or contains a bituminous nucleus.

The origin of bitumen is as little known as that of most of the productions of nature. Some regard it as an empyreumatic oil, a matter analogous to liquid resin or essential oil, resulting from the destruction of that astonishing multitude of animals and vegetables buried in the earth, whose solid remains are daily brought to view in mineral researches. It has been also supposed that naptha and petroleum are the product of coals decomposed either by the fire of volcanoes, by the subterranean combustion of coal itself, or by the decomposition of pyrites. The latter opinion is not supported by any direct evidence, but the two former are sufficiently probable.

Elastic Bitumen is a rare substance, found hitherto only near Castleton, in Derbyshire, in fissures of slaty clay.

Bituminous mastic, or cement, has been of late extensively employed in France for covering roofs and terraces, and lining water-cisterns. The mineral bitumen used for the composition of this mastic is procured chiefly from the *Obsann* (Bas-Rhin), from the Parc (department de l'Ain), and from the *Puy-de-la-Poix* (department of Puy-de-Dome). But boiled coal tar answers pretty well. In the neighborhood of those localities, there is a limestone impregnated with bitumen which suits for giving consistence to the cement. This is well dried, ground to powder, sifted, and stirred while hot, in about one fifth its weight of melted asphaltum, contained in a cast iron boiler. Dry chalk or bricks, ground and sifted, will suit equally well. As soon as this paste is made quite homogeneous, it is lifted out with an iron shovel or spoon, and spread in rectangular moulds, secured with pegs at the joints, fastened to a kind of platform of smoothed planks, covered with strong sheet-iron. The sides of these moulds should be previously smeared over with a thin coat of loam-paste, to prevent their adhesion to the mastic. Whenever the cake is cold, the frame is taken asunder, and it is removed from the iron plate by an oblong shovel, or strong spatula of iron. These cakes or bricks are usually 18 inches long, 12 broad and 4 thick, and weigh about 70 lbs.

It is a very remarkable fact, in the history of the useful arts, that asphalt, which

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was so generally employed as a solid and durable cement in the earliest constructions upon record, as in the walls of Babylon, should for so many thousand years have fallen well nigh into disuse among civilized nations. For there is certainly no class of mineral substance so well fitted as the bituminous by their plasticity, fusibility, tenacity, adhesiveness to surfaces, impenetrability by water, and unchangeableness in the atmosphere, to enter into the composition of terraces, foot-pavements, roofs, and every kind of hydraulic work. Bitumen, combined with calcareous earth, forms a compact, semi-elastic solid, which is not liable to suffer injury by the greatest alternations of frost and thaw, which often disintegrate in a few years the hardest stone, nor can it be ground to dust and worn away by the attrition of the feet of men and animals, as sandstone, flags, and even blocks of granite are. An asphalt pavement, rightly tempered in tenacity, solidity, and elasticity, seems to be incapable of suffering abrasion in the most crowded thoroughfares; a fact exemplified of late in a few places in London, but much more extensively, and for a much longer time in Paris.

The great Place de la Concorde (formerly Place Louis Quinze) is covered with a beautiful mosaic pavement of asphalt; many of the promenades on the Boulevards, formerly so filthy in wet weather, are now covered with a thin bed of bituminous mastic, free alike from dust and mud; the foot-paths of the Pont Royal and Pont Carousel, and the areas of the great public slaughter-houses, have been for several years paved in a similar manner with perfect success. It is much to be regretted that the asphalt companies of London made the ill-judged, and nearly abortive attempt, to pave the carriage-way near the east end of Oxford street, and especially at a moist season, most unpropitious to the laying of bituminous mastich. Being formed of blocks not more than three or four inches thick, many of which contained much siliceous sand, such a pavement could not possibly resist the crash and vibration of many thousand heavy drays, wagons, and omnibuses, daily rolling over it.* This failure can afford, however, no argument against rightly-constructed foot-pavements and terraces of asphalt. Numerous experiments and observations have led me to conclude that fossil bitumen possesses far more valuable properties, for making a durable mastich, than the solid pitch obtained by boiling wood or coal tar. The latter, when inspissated to a proper degree of hardness, becomes brittle, and may be readily crushed into powder; while the former, in like circumstances, retains sufficient tenacity to resist abrasion. Factitious tar and pitch being generated by the force of fire, seem to have a propensity to decompose by the joint agency of water and air, whereas mineral pitch has been known to remain for ages without alteration.

Bitumen alone is not so well adapted for making a substantial mastich as the native compound of bitumen and calcareous earth, which has been properly called asphaltic rock, of which the richest and most extensive mine is unquestionably that of the *Val-de-Travers,* in the canton of Neufchâtel. This interesting mineral deposite occurs in the Jurassic limestone formation, the equivalent of the English oolite. The mine is very accessible, and may be readily excavated by blasting with gunpowder. The stone is massive, of irregular fracture, of a liver-brown color, and is interspersed with a few minute spangles of calcareous spar. Though it may be scratched with the nail, it is difficult to break by the hammer. When exposed to a very moderate heat it exhales a fragrant ambrosial smell, a property which at once distinguishes it from all compounds of factitious bitumen. Its specific gravity is 2·114, water being 1,000, being nearly the density of bricks. It may be most conveniently analyzed by digesting it in successive portions of hot oil of turpentine, whereby it affords 80 parts of a white pulverulent carbonic of lime, and 20 parts of bitumen in 100. The asphalt rock of Val-de-Travers seems therefore to be far richer than that of Pyrimont, which, according to the statement in the specification of Claridge's patent, of November, 1837, contains "carbonate of lime and bitumen in about the proportion of 90 parts of carbonate of lime to about 10 parts of bitumen."

The calcareous matter is so intimately combined and penetrated with the bitumen, as to resist the action not only of air and water for any length of time, but even of muriatic acid; a circumstance partly due to the total absence of moisture in the mineral, but chiefly to the vast incumbent pressure under which the two materials have been incorporated in the bowels of the earth. It would indeed be a difficult matter to combine, by artificial methods, calcareous earth thus intimately with bitumen, and for this reason the mastichs made in this way are found to be much more perishable. Many of the factitious asphalt cements contain a considerable quantity of siliceous sand, from which they derive the property of cracking and crumbling down when trodden upon. In fact, there seems to be so little attraction between siliceous matter and bitumen, that their parts separate from each other by a very small disruptive force.

Since the asphalt rock of Val-de-Travers is naturally rich enough in concrete bitumen, it may be converted into a plastic workable mastic of excellent quality for foot pavements and hydraulic works at very little expense, merely by the addition of a very small quantity of mineral or coal tar, amounting to not more than 6 or 8 per cent. The union between these materials may be effected in an iron cauldron, by the application of a very moderate heat, as the asphalt bitumen readily coalesces with the tar into a tenacious solid.

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* See the conclusion of this article.

The mode adopted for making the beautiful asphalt pavement at the Place de la Concorde in Paris was as follows:—The ground was made uniformly smooth, either in a horizontal plane or with a gentle slope to carry off the water; the curb-stones were then laid round the margin by the mason about 4 inches above the level of the ground. This hollow space was filled to a depth of 3 inches with concrete, containing about a sixth part of hydraulic lime, well pressed upon its bed. The surface was next smoothed with a thin coat of mortar. When the whole mass had become perfectly dry, the mosaic pattern was set out on the surface, the moulds being formed of flat iron bars, rings, &c. about half an inch thick, into which the fluid mastic was poured by ladles from a cauldron, and spread evenly over.

The mastic was made in the following way:—The asphalt rock was first of all roasted in an oven, about 10 feet long and 3 broad in order to render it friable. The bottom of the oven was sheet iron, heated below by a brisk fire. A volatile matter exhaled, probably of the nature of naptha, to the amount of one-fortieth the weight of asphalt; after roasting, the asphalt became so friable, as to be easily reduced to powder, and passed through a sieve, having meshes about one-fourth of an inch square.

The bitumen destined to render the asphalt fusible and plastic was melted in small quantities at a time, in an iron cauldron, and then the asphalt in powder was gradually stirred in to the amount of 12 or 13 times the weight of bitumen. When the mixture became fluid, nearly a bucketful of very small, clean gravel, previously heated apart, was stirred into it; and, as soon as the whole began to simmer with a treacley consistence, it was fit for use. It was transported in buckets, and poured into the moulds.

For the reasons above assigned, I consider this addition of rounded, polished, siliceous stones to be very injudicious. If anything of the kind be wanted to give solidity to the pavement, it should be a granitic or hard calcareous sand, whose angular form will secure the cohesion of the mass. I conceive, also, that tar, in moderate quantity, should be used to give toughness to the asphaltic combination, and prevent its being pulverized and abraded by friction.

In the able report of the Bastenne and Gaujac Bitumen company, drawn up by Messrs. Goldsmid and Russell, these gentlemen have made an interesting comparison between the properties of mineral tar and vegetable tar: the bitumen composed of the latter substance, including various modifications, extracted from coal and gas, have, so far as they were able to ascertain, entirely failed. This bitumen, owing to the qualities and defects of vegetable tar, becomes soft at 115° of Fahrenheit's scale, and is brittle at the freezing point; while the bitumen, into which mineral tar enters, will sustain 170° of heat, without injury. In the course of the winter, 1837–'38, when the cold was at 14½° below zero, C., the bitumen of Bastenne and Gaujac, with which one side of the Pont Neuf at Paris is paved, was not at all impaired, and would, apparently, have resisted any degree of cold; while that in some parts of the Boulevard, which was composed of vegetable tar, cracked and opened in white fissures. The French government, instructed by these experiments, has required, when any of the vegetable bitumens are laid, that the pavement should be an inch and a quarter thick; whereas, where the bitumen composed of mineral tar is used, a thickness of three quarters of an inch is deemed sufficient. The pavement of the bonding warehouse at Bordeaux has been laid upward of 15 years by the Bastenne company, and is now in a condition as perfect as when first formed. The reservoirs constructed to contain the waters of the Seine at Batignolles, near Paris, have been mounted 6 years, and, notwithstanding the intense cold of the winter of 1837, which froze the whole of their contents into one solid mass, and the perpetual water pressure to which they are exposed, they have not betrayed the slightest imperfection in any point. The repairs done to the ancient fortifications at Bayonne, have answered so well, that the government, 2 years ago, entered into a very large contract with the company for additional works, while the whole of the arches of the St. Germain and St. Cloud railways, and the pavements and floorings necessary for these works, are being laid with the Bastenne bitumen.

The mineral tar in the mines of Bastenne and Gaujac is easily separated from the earthy matter with which it is naturally mixed by the process of boiling, and is then transported in barrels to Paris or London, being laid down in the latter place to the company at 17*l.* per ton, in virtue of a monopoly of the article purchased by the company at a sum, it is said, of 8,000*l.*

Mr. Harvey, the able superintendent of the Bastenne company, was good enough to supply me with various samples of mineral tar, bitumen, and asphaltic rock, for

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analysis. The tar of Bastenne is an exceedingly viscid mass, without any earthy impurity. It has the consistence of bakers' dough at 60° of Fahrenheit; at 80° it yields to the slightest pressure of the finger; at 150° it resembles a soft extract; and at 212° it has the fluidity of molasses. It is admirably adapted to give plasticity to the calcareous asphalts.

A specimen of Egyptian asphalt which he brought me, gave by analysis the very same composition as the Val de Travers, namely, 80 per cent. of pure carbonate of lime, and 20 of bitumen. A specimen to mastic, prepared in France, was found to consist, in 100 parts, of 29 of bitumen, 52 of carbonate of lime, and 19 of silicious sand. A portion of stone called the natural Bastenne rock afforded me 80 parts of gritty silicious matter and 20 of thick tar. The Trinidad bitumen contains a considerable portion of foreign earthy matter; one specimen yielded me 25 per cent. of silicious sand; a second, 28; a third, 20; and a fourth, 30: the remainder was pure pitch. One specimen of Egyptian bitumen, specific gravity 1·2, was found to be perfectly pure, for it dissolved in oil of turpentine without leaving any appreciable residuum.

Robinson's Parisian Bitumen company use a mastich made with the pitch obtained from boiling coal-tar mixed with chalk. One piece laid down by this company at Knightsbridge and another at Brighton, are said to have gone to pieces. The portion of pavement laid down by them in Oxford street, next Charles street, has been taken up. Claridge's company have laid down their mastich under the archway of the Horse-Guards, and in the carriage-entrance at the Ordnance Office; the latter has cracked at the junction with the old pavement of Yorkshire curb-stone. The foot-pavement laid down by Claridge's company at Whitehall has stood well. The Bastenne company has exhibited the best specimen of asphalt pavement in Oxford street; they have laid down an excellent piece of foot-pavement near Northumberland House; a piece, 40 feet by 7, on Blackfriars' Bridge; they have made a substantial job in paving 830 superficial feet in front of the guard-room at Woolwich, which, though much traversed by foot-passengers, and beat by the guard in grounding arms, remains sound; lastly, the floor of the stalls belonging to the cavalry barracks of the Blues at Knightsbridge, is probably the best example of asphaltic pavement laid down in this country, as it has received no injury from the beating of the horses' feet.

As the specific gravity of properly-made mastich is nearly double that of water, a cubic foot of it will weigh from 125 to 130 lbs.; and a square foot, three quarters of an inch thick, will weigh very nearly eight pounds. A ton of it will therefore cover 280 square feet. The prices at which the Bastenne Bitumen company sell their products is as follows:—

Pure Mineral tar, 24*l.* per ton, or 28*s.* per cwt.
Mastich 8*l.* 8*s.* per ton, or 10*s.* per cwt.

			Side Pavement.			Roofs and Terraces.
From	50 to	100 feet,	1*s.* 3*d.* per foot.		-	1*s.* 6*d.* per foot.
	100	250	1*s.* 1*d.*	-	-	1*s.* 4*d.*
	250	500	11*d.*	-	-	1*s.* 1*d.*
	500	750	10*d.*	-	-	1*s.* 0*d.*
	750	1000	9*d.*	-	-	11*d.*
	1000	2000	8*d.*	-	-	10*d.*
	2000	5000	7*d.*	-	-	9*d.*

Where the work exceeds 5,000 feet, contracts may be entered into.

For filling up joints of brickwork, &c., from 1*d.* to 1¼*d.* per foot, run according to quantity.

These prices are calculated for half an inch thickness, at which rate a ton will cover 420 square feet.

As the Val-de-Travers company engage to lay down their rich asphaltic rock in London at 5*l.* per ton; and as the mineral tar equal to that of Seissel may probably be had in England at one fourth the price of that foreign article, they may afford to lay their mastich three quarters of an inch thick per the thousand feet, including a substratum of concrete, at a rate of fivepence per square foot, instead of fifteenpence, being the rate charged under that condition by the Bastenne company.

These charges are for London and its immediate vicinity.

Report of the experimental Pavements laid down in Oxford street, from Charles street to Tottenham Court Road, January, 1839.

1. Robinson's Parisian bitumen, laid in blocks 12 inches square and 5 inches deep; the substance is a compound of bitumen, lime, &c., and five granite stones are inserted in the top of each block; the work is laid in straight courses, the joints cemented with hot bitumen. The quantity of this is 97 square yards, the length is 20 feet, and the price, if adopted, 9*s.* per square yard.

2. Same as 1, but the courses laid diagonally. The quantity is 97 square yards, the length is 20 feet.

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3. Granite paving, 9 inches deep, joined with Clarige's asphalt, the work laid in straight courses. The cost to the parish has been 11 *s.* 7 *d.* per yard superficial for the stone and laying, &c., no charge being made by Claridge's Company for the asphalt. The quantity is 240 yards, the length 54 feet.

4. Granite paving, 4½ inches deep, jointed with Claridge's asphalt, the work laid in diagonal courses. Cost to the parish 9*s.* 6*d.* per square yard. No charge made for the asphalt. The quantity is 88 square yards, the length 20 feet.

5. The Bastenne Bitumen Company. The blocks are 12 inches long, 6¼ wide, and 3¾ deep with bevelled joints, close at bottom, and ½ inch open at top; the joints cemented with hot bitumen; the substance is bituminous, with a very large proportion of granite imbedded in each block; the price, if adopted, 13*s.* 6*d.* per square yard; the length in straight courses, 20 feet.

6. Same as 5, but the courses laid diagonally. The length 40 feet; the total quantity in 5 and 6 is 274 square yards.

7. Aberdeen granite paving, 9 inches deep; laid on a concrete bottom, formed of gravel and lime, the joints of the pavement run with hot lime grout, in straight courses The length is 69 feet; cost, 16*s.* 5*d.* per square yard.

8. Same as 7, but the courses laid diagonally; length 38 feet.

9. Aberdeen granite paving, 9 inches deep, in straight courses, without a concrete bottom; joints filled with fine gravel; cost, 12*s.* 5*d.* per yard; length, 24 feet.

10. The Scotch Asphaltum company. The work is laid in blocks of divers length, 9 inches wide, and 6½ deep; the side joints are straight, the end joints are bevelled alternately. The work is laid in straight courses, and jointed in Roman cement; the substance is, apparently, a bituminous matter mixed with fine gravel. The length is 50 feet; the number of square yards, 210; the price, per yard, if adopted, 13*s.* 6*d.*

11. The wood-paving. The blocks are sexagon on the plan, and (with the exception of a few courses that are only 8 inches), 12 inches deep. The work is laid endwise of the grain; the blocks are mostly 8 inches diameter—a few courses are 7 inches. The material is Norway fir; there is no prepared bottom—the blocks are laid on the plain ground, a small layer of gravel being spread to bed them in. From the west end, 22 rows of courses of blocks are of wood in its natural state; 31 rows have been Kyanised; 9 rows at the eastern end have been dipped in Claridge's asphalt; 6 rows have been dipped in a solution prepared by the patentee; the remainder are of wood in the natural state. The length of this piece is 60 feet: the number of yards, 230; price per yard, if approved, 10*s.* 6*d.*

12. Val-de-Travers company. Blocks in straight courses, 12 inches square, 5 inches deep, with square joints. The substance of the blocks is bituminous, with a very large proportion of granite imbedded in each block, the joints cemented with hot bitumen. The length is 25 feet; number of square yards 94; the work is performed gratuitously.

13. The same company. A layer of clean chippings and hot asphalt poured thereon The face up, with hot asphalt and broken stone imbedded therein. The length is 25 feet: number of yards, 94; the work is gratuitous.

14. Same as 9. The length 47 feet.

By order of the Committee,
H. Kensett, Chairman.

Statement of the number of carriages passing through Oxford street at the undernamed times and places.

Date. 1839.	Time.	Place.	Gents. 2-Wheel.	Gents. 4-Wheel.	Omnibuses.	2-Wheel Hackney Carriages.	4-Wheel Hackney Carriages.	Stage Coaches.	Wagons, Drays, &c.	Light Carts and Sundries.	Total.
Jan. 16.	6 in the morning till 12 at	by the Pantheon.	347	935	890	621	752	91	372	1507	5515
18.	do. [night.	by Stratford place.	254	603	1213	401	728	89	472	993	4753
22.	do.	by Newman street.	339	1241	1015	584	1288	85	958	1382	6992
26.	do. [morning.	by Stratford place.	371	766	1337	542	762	92	881	1292	5943
26.	12 at night till 6 in the	do.	—	4	1	82	139	2	38	58	324

The asphalt pavements were, in my judgment, so imperfectly constructed with coal tar, ill boiled and aqueous, as to have a crumbling property when exposed to vicissitudes of weather. Native bitumen makes a far better and more durable cement.

BLACK DYE. (*Teinte noire,* Fr.; *Schwartze farbe,* Germ.) For 1 cwt. of cloth there are put into a boiler of middle size 18lbs. of logwood with as much Aleppo galls in powder, and the whole, being enclosed in a bag, is boiled in a sufficient quantity of water for 12 hours. One-third of this bath is transferred into another boiler with two pounds of verdigris; and the stuff is passed through this solution, stirring it continually during two hours, taking care to keep the bath very hot without boiling. The stuff is then lifted out, another third of the bath is added to the boiler, along with 8 pounds of sulphate of iron or green vitriol. The fire is to be lowered while the sulphate dissolves, and the bath is allowed to cool for half an hour, after which the stuff is introduced, and well moved about for an hour, and then it is taken out to air. Lastly, the remaining third of the bath is added to the other two, taking care to squeeze the bag well. 18 or 22 lbs. of sumach are thrown in; the whole is just brought to a boil, and then refreshed with a little cold water; 2 pounds more of sulphate of iron are added, after which the stuff is turned through for an hour. It is next washed, aired, and put again into the bath, stirring it continually for an hour. After this, it is carried to the river, washed well, and then fulled. Whenever the water runs off clear, a bath is prepared with weld, which is made to boil for an instant; and after refreshing the bath the stuff is turned in to soften, and to render the black more fast. In this manner, a very beautiful black is obtained without rendering the cloth too harsh.

Commonly more simple processes are employed. Thus the blue cloth is simply turned through a bath of gall-nuts, where it is boiled for two hours. It is next passed through a bath of logwood and sulphate of iron for two hours, without boiling, after which it is washed and fulled. But in all cases the cloth, after passing through the blue vat, should be thoroughly washed, because the least remains of its alkalinity would injure the tone to be given in the black copper.

Hellot has found that the dyeing might be performed in the following manner:—For 20 yards of dark blue cloth, a bath is made of 2 lbs. of fustic (*morus tinctoria*), 4¼ lbs. logwood, and 11 lbs of sumach. After boiling the cloth in it for three hours it is lifted out, 11 lbs. of sulphate of iron are thrown into the boiler, and the cloth is then passed through it during two hours. It is now aired, and put again in the bath for an hour. It is, lastly, washed and scoured. The black is less velvety than that by the preceding process. Experience convinced him that the maddering prescribed in the ancient regulations only gives a reddish cast to the black, which is obtained finer and more velvety without madder.

A black may be dyed likewise without having given a blue ground. This method is employed for cloths of little value. In this case they are rooted; that is to say, they receive a dun ground with walnut husks, or the root of the walnut tree, and are afterwards made black in the manner above described, or in some other way; for it is obvious that a black may be obtained by several processes.

According to Lewis, the proportions which the English dyers most generally adopt are, for 112 lbs. of woollen cloth previously dyed of a dark blue, about 5 lbs. of sulphate of iron, as much gall-nuts, and 30 lbs. of logwood. They begin by galling the cloth, they then pass it through the decoction of logwood, to which the sulphate of iron has been added.

When the cloth is completely dyed, it is washed in the river, and passed through the fulling-mill till the water runs off clear and colorless. Some persons recommend, for fine cloths, to full them with soap water. This operation requires an expert workman, who can free the cloth thoroughly from the soap. Several recommend at its coming from the fulling to pass the cloth through a bath of weld, with the view of giving softness and solidity to the black. Lewis says, that passing the cloth through weld, after it has been treated with soap, is absolutely useless, although it may be beneficial when this operation has been neglected.

The following German process is cheap and good. 100 lbs of cloth or wool are put into the copper with sufficient water and 15 lbs. of Salzburg vitriol (potash-sulphate of iron) and 5 lbs. of argol, heating the bath gradually to boiling, while the goods are well worked about for two hours, taking them out, and laying them in a cool place for twenty-four hours. They are then to be put in a lukewarm bath of from 25 lbs. to 30 lbs. of logwood, and 10 lbs. of fustic, and to be worked therein while it is made to boil during two hours. The goods are now removed, and there is put into the copper 1¼ lbs. of verdigris, dissolved in vinegar; the goods are restored into the improved bath, and turned in it for half an hour, after which they are rinsed and dried.

The process for dyeing merinos black is for 100 lbs. of them to put 10 lbs. of copperas into the bath of pure water, and to work therein for a quarter of an hour, as soon as it is tepid, one-third of the goods; then to replace that portion by the second, and after another quarter of an hour, to put in the last third. Each portion is to be laid aside to air in the cold. The bath being next heated to 140° F., the merinos are to be treated as above piecemeal; but the third time it is to be passed through the bath at a boiling heat. Being now well mordanted, the goods are laid aside to air till the following day. The copper being charged with water, 50 lbs. of ground logwood and 2 lbs. of argol, and heated, the goods are to be passed through while boiling for half an hour They are then rinsed.

Different operations may be distinguished in dyeing *silk* black; the boiling of the silk, its galling, the preparation of the bath, the operation of dyeing, the softening of the black.

Silk naturally contains a substance called gum, which gives it the stiffness and elasticity peculiar to it in its native state; but this adds nothing to the strength of the silk, which is then styled raw; it rather renders it, indeed, more apt to wear out by the stiffness which it communicates; and although raw silk more readily takes a black color, yet the black is not so perfect in intensity, nor does it so well resist the re-agents capable of dissolving the coloring particles, as silk which is scoured or deprived of its gum.

To cleanse silk intended for black, it is usually boiled four or five hours with one fifth of its weight of white soap, after which it is carefully beetled and washed.

For the galling, nut-galls equal nearly to three fourths of the weight of the silk are boiled during three or four hours; but on account of the price of Aleppo galls, more or less of the white gall-nuts, or of even an inferior kind called galon, berry or apple galls, are used. The proportion commonly employed at Paris is two parts of Aleppo galls to from eight to ten parts of galon. After the boiling, the galls are allowed to settle for about two hours. The silk is then plunged into the bath, and left in it from twelve to thirty-six hours, after which it is taken out and washed in the river.

Silk is capable of combining with quantities, more or less considerable, of the astringent principle; whence results a considerable increase of weight, not only from the weight of the astringent principle, but also from that of the coloring particles, which subsequently fix themselves in proportion to the quantity of the astringent principle which had entered into combination. Consequently the processes are varied according to the degree of weight which it is wished to communicate to the silk; a circumstance requiring some illustration.

The commerce of silk goods is carried on in two ways; they are sold either by the weight, or by the surface, that is, by measure. Thus the trade of Tours was formerly distinguished from that of Lyons; the silks of the former being sold by weight, those of the latter, by measure. It was therefore their interest to surcharge the weight at Tours, and, on the contrary, to be sparing of the dyeing ingredients at Lyons; whence came the distinction of light black and heavy black. At present, both methods of dyeing are practised at Lyons, the two modes of sale having been adopted there.

Silk loses nearly a fourth of its weight by a thorough boiling, and it resumes, in the light black dye, one half of this loss; but in the heavy black dye, it takes sometimes upwards of a fifth more than its primitive weight; a surcharge injurious to the beauty of the black, and the durability of the stuff. The surcharged kind is denominated English black, because it is pretended that it was first practised in England. Since silk dyed with a great surcharge has not a beautiful black, it is usually destined for weft, and is blended with a warp dyed of a fine black.

The peculiarity of the process for obtaining the heavy black consists in leaving the silk longer in the gall liquor, in repeating the galling, in passing the silk a greater number of times through the dye, and even letting it lie in it for some time. The first galling is usually made with galls which have served for a preceding operation, and fresh gall-nuts are employed for the second. But these methods would not be sufficient for giving a great surcharge, such as is found in what is called the English black. To give it this weight, the silk is galled without being ungummed; and, on coming out of the galls, it is rendered supple by being worked on the jack and pin.

The silk-dyers keep a black vat, and its very complex composition varies in different dye-houses. These vats are commonly established for many years: and when their black dye is exhausted it is renovated by what is called in France a *brevet*. When the deposite which has accumulated in it is too great, it is taken out, so that at the end of a certain time nothing remains of the several ingredients which composed the primitive bath, but which are not employed in the brevet.

For the dyeing of raw silk black, it is galled in the cold, with the bath of galls which has already served for the black of boiled silk. For this purpose, silk, in its native yellow color, is made choice of. It should be remarked, that when it is desired to preserve a portion of the gum of the silk, which is afterwards made flexible, the galling is given with the hot bath of gall-nuts in the ordinary manner. But here, where the whole gum of the silk, and its concomitant elasticity, are to be preserved, the galling is made in the cold. If the infusion of galls be weak, the silk is left in it for several days.

Silk thus prepared and washed takes very easily the black dye, and the rinsing in a little water, to which sulphate of iron may be added, is sufficient to give it. The dye is made in the cold; but, according to the greater or less strength of the rinsings, it requires more or less time. Occasionally three or four days are necessary; after which it is washed, it is beetled once or twice, and it is then dried without wringing, to avoid softening it.

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Raw silk may be more quickly dyed, by shaking it round the rods in the cold bath after the galling, airing it, and repeating these manipulations several times, after which it is washed and dried as above.

Macquer describes a more simple process for the black by which velvet is dyed at Genoa; and he says that this process, rendered still simpler, has had complete success at Tours. The following is his description.

For 1 cwt. (50 kilogrammes) silk, 22 lbs. (11 kilogrammes) of Aleppo galls, in powder, are boiled for an hour in a sufficient quantity of water. The bath is allowed to settle till the galls have fallen to the bottom of the boiler, from which they are withdrawn; after which 32 lbs. of English vitriol (or copperas) are introduced, with 13 lbs. of iron-filings, and 22 lbs of country gum, put into a kind of two-handled cullender, pierced every where with holes. This kettle is suspended by two rods in the boiler, so as not to reach the bottom. The gum is left to dissolve for about an hour, stirring it from time to time. If, after this time, some gum remains in the kettle, it is a proof that the bath, which contains two hogsheads, has taken as much of it as is necessary. If, on the contrary, the whole gum is dissolved, from 1 to 4 lbs. more may be added. This cullender is left constantly suspended in the boiler, from which it is removed only when the dyeing is going on; and afterwards it is replaced. During all these operations the boiler must be kept hot, but without boiling. The galling of the silk is performed with one third of Aleppo galls. The silk is left in it for six hours the first time, then for twelve hours. The rest, *secundum artem.*

Lewis states that he has repeated this process in the small way; and that by adding sulphate of iron progressively, and repeating the immersions of the silk a great number of times, he eventually obtained a fine black.

Astringents differ from one another as to the quantity of the principle which enters into combination with the oxyde of iron. Hence, the proportion of the sulphate, or of any other salt of iron, and that of the astringents, should vary according to the astringents made use of, and according to their respective quantities. Gall-nut is the substance which contains most astringent; sumach, which seems second to it in this respect, throws down (decomposes), however, only half as much sulphate of iron.

The most suitable proportion of sulphate of iron appears to be that which corresponds to the quantity of the astringent matter, so that the whole iron precipitable by the astringent may be thrown down, and the whole astringent may be taken up in combination with the iron. As it is not possible, however, to arrive at such precision, it is better that the sulphate of iron should predominate, because the astringent, when in excess, counteracts the precipitation of the black coloring particles, and has the property of even dissolving them.

This action of the astringent is such that, if a pattern of black cloth be boiled with gall-nuts, it is reducible to gray. An observation of Lewis may thence be explained. If cloth be turned several times through the coloring bath, after it has taken a good black color, instead of acquiring more body, it is weakened, and becomes brownish. Too considerable a quantity of the ingredients produces the same effect; to which the sulphuric acid, set at liberty by the precipitation of the oxyde of iron, contributes.

It is merely the highly oxydized sulphate which is decomposed by the astringent; whence it appears, that the sulphate will produce a different effect according to its state of oxydizement, and call for other proportions. Some advise, therefore, to follow the method of Proust, employing it in the oxydized state; but in this case it is only partially decomposed, and another part is brought, by the action of the astringent, into the lower degree of oxydizement.

The particles precipitated by the mixture of an astringent and sulphate of iron have not at first a deep color; but they pass to a black by contact of air while they are moist.

Under *dyeing* I shall show that the black dye is only a very condensed color, and that it assumes more intensity from the mixture of different colors likewise deep. It is for this reason advantageous to unite several astringents, each combination of which produces a different shade. But blue appears the color most conducive to this effect, and it corrects the tendency to dun, which is remarked in the black produced on stuffs by the other astringents.

On this property is founded the practice of giving a blue ground to black cloths, which acquire more beauty and solidity the deeper the blue. Another advantage of this practice is to diminish the quantity of sulphuric acid which is necessarily disengaged by the precipitation of the black particles, and which would not only counteract their fixation, but would further weaken the stuff, and give it harshness.

For common stuffs, a portion of the effect of the blue ground is produced by the rooting.

The mixture of logwood with astringents contributes to the beauty of the black in a twofold way. It produces molecules of a hue different from what the astringents do,

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and particularly blue molecules, with the oxide of copper, commonly employed in the black dyes; which appears to be more useful the more acetate the verdigris made use of contains.

The boil of weld, by which the dye of black cloth is frequently finished, may also contribute to its beauty, by the shade peculiar to its combination. It has, moreover, the advantage of giving softness to the stuffs.

The processes that are employed for wool yield, according to the observation of Lewis, only a rusty black to silk; and cotton is hardly dyed by the process proper for wool and silk. Let us endeavor to ascertain the conditions which these three varieties of dyeing demand.

Wool has a great tendency to combine with coloring substances; but its physical nature requires its combinations to be made in general at a high temperature. The combination of the black molecules may therefore be directly effected in a bath, in proportion as they form; and if the operation be prolonged by subdividing it, it is only with the view of changing the necessary oxidizement of the sulphate, and augmenting that of the coloring particles themselves.

Silk has little disposition to unite with the black particles. It seems to be merely by the agency of the tannin, with which it is previously impregnated, that these particles can fix themselves on it, especially after it has been scoured. For this reason, silk baths should be old, and have the coloring particles accumulated in them, but so feebly suspended as to yield to a weak affinity. Their precipitation is counteracted by the addition of gum, or other mucilaginous substances. The obstacles which might arise from the sulphuric acid set at liberty is destroyed by iron filings, or other basis. Thus, baths of a very different composition, but with the essential condition of age, may be proper for this dye. For cotton black dye, see Calico Printing.

Blue-black dye.—The mordant much employed in some parts of Germany for this dye, with logwood, galls, sumach, &c., is *iron-alum*, so called on account of its having the crystalline form of alum, though it contains no alumina. It is prepared by dissolving 78 pounds of red oxide of iron in 117 pounds of sulphuric acid, diluting this compound with water, adding to the mixture 87 pounds of sulphate of potash, evaporating the solution to the crystallizing point. This potash sulphate of iron has a fine amethyst color when recently prepared; and though it gets coated in the air with a yellowish crust, it is none the worse on this account. As a mordant, a solution of this salt, in from 6 to 60 parts of water, serves to communicate and fix a great variety of uniform ground colors, from light gray to brown, blue, or jet black, with quercitron, galls, logwood, sumach, &c., separate or combined. The above solution may be usefully modified by adding to every 10 pounds of the *iron-alum*, dissolved in 8 gallons (80 pounds) of warm water, 10 pounds of acetate (sugar) of lead, and leaving the mixture, after careful stirring, to settle. Sulphate of lead falls, and the oxide of iron remains combined with the acetic acid and the potash. After passing through the above mordant, the cotton goods should be quickly dried.

BLACK PIGMENT. The finest light black is prepared principally for the manufacturing of printers' ink. In Messrs. Martin and Grafton's patent process, the black is obtained by burning common coal-tar, which should, however, be previously divested, as much as possible, of the ammoniacal liquor and acid mixed with it in the tank.

For this purpose, it is proposed that four casks should be employed, each capable of holding 130 gallons, and into every one of them are to be put about 60 gallons of the rough impure tar, to which an equal quantity of lime-water is to be added, and then agitated by machinery or manual labor until the lime-water is completely mixed with the tar. The vessels should next be suffered to rest for about six hours, by which time the tar will settle at the bottom of the casks, and the water may be drawn off. The casks containing the tar should now be filled with hot water, which may be supplied from the boiler of a steam engine, and the whole again agitated as before. This process may be repeated three times, suffering the tar to subside between each; and twelve hours should be allowed for settling from the last water, so that the whole of the tar and water may become separated, the water rising to the top of the cask, and the tar being left at the bottom in a pure state.

But, as some of the water will yet remain mechanically combined with the tar, it is proposed that the tar should be subjected to the process of distillation. For this purpose, a still, capable of holding 120 gallons, may be employed, in which about 50 gallons at one time may be operated upon; when, by a gentle heat, the water, and other impurities which the tar may have retained, will be driven off. As soon as the water appears to have evaporated, and the spirit runs fine and clear, the process of distillation should be stopped; and, when cold, the pure tar may be drawn off, and set apart for the purpose of being employed as contemplated in the patent.

The tar thus purified may be now converted into black, or it may be subjected to urther rectification to divest it of the mineral pitch, or asphaltum, which is combined with the oil and spirit: the latter is to be preferred, because the mineral pitch, or asphaltum, is only inflammable at a high temperature, which renders it more troublesome to use in the process here contemplated, and also would cause the apparatus to require frequent cleaning from the carbonized pitch deposited. In order, therefore, to get rid of the mineral pitch, or asphaltum, forty gallons of the tar are to be introduced into a still, as before; and, instead of stopping the operation, as soon as the spirit begins to come over, the distillation is continued with a strong heat, so as to force over the whole of the oil and spirit, leaving the residuum of asphaltum in the still; this process, however, is known to every chemist, and need not be further explained.

In *fig.* 128, is exhibited a rude representation of the apparatus employed in preparing and collecting the fine light spirit black, produced by the combustion of the oil and spirit of coal-tar after it has been purified as above described. *a* is the brickwork which supports a number of burners issuing from a tube, *b*, within, and here shown by dots, as passing along its whole length. *Fig.* 129. is a section of the brickwork, with the tube burner, and receiver, as will be described hereafter. The tube may be called the tar main, as it is intended to be filled with tar: it is constructed of cast iron, and from it issue several (in this figure twenty-four) jets or burners, *c. c, c;* any other number may be employed. *d* is a furnace under the tar main, the flue of which extends along, for the purpose of heating the tar to the boiling point, in order to facilitate the process. Erom the main, *b,* the tar flows into the jets *c*; wicks are introduced into the jets, and, when set fire to by a red-hot stick, will burn and emit a very considerable quantity of smoke; which it is the object of this apparatus to conduct through many passages, for the purpose of collecting its sooty particles.

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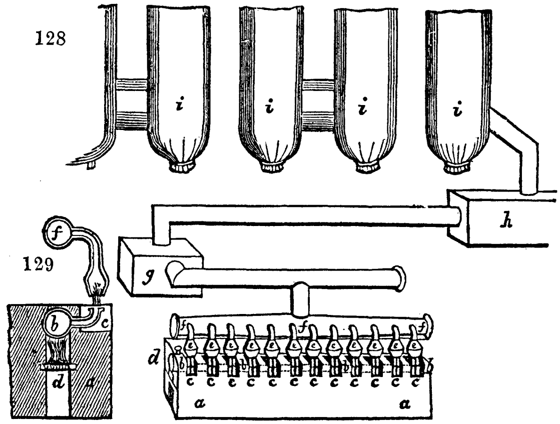

There are a number of hoods, *e, e, e,* or bonnets, as they are termed, all of which, through their pipes, have communication with or lead into, a main chimney, *f, f.* Into these hoods or bonnets the smoke of the burners ascends, and from thence passes into the main chimney *f,* and thence through the smoke tubes into the box *g;* here the heaviest particles of the black deposit themselves; but, as the smoke passes on through the farthest pipes, a deposit of the second, or finer, particles of black takes place in the box, *h.* From hence the smoke proceeds through other pipes into a series of canvas bags, *i, i, i,* which are proposed to be about 18 feet long, and 3 in diameter. These bags are connected together at top and bottom alternately, and through the whole series the smoke passes up one bag and down the next, depositing fine black, called spirit black, upon the sides of the convas. After the jets have continued burning for several days, the bags are to be beaten with a stick, so that the black may fall to th bottom; and when a sufficient quantity has accumulated, the bags may be emptied and swept out. Thus seventy or eighty bags may be employed; so that the smoke should pass through a length of about 400 yards, the farthest of which will be found to contain the finest black. The last bag should be left open, in order to allow the vapor to escape into the open air.

The main tar tube will require to be emptied every four or five days, in order to clear it from the pitchy matter that may have subsided from the burners, and they also will require to be frequently poked with a wire, to clear off the black which forms upon the edges, and to drive down the carbonized tar which attaches itself to the upper part of the jets.

A fine lamp-black is obtained by the combustion of a thick torch of coal-gas, supplied with a quantity of air adequate to burn only its hydrogen. In this case, the whole of its carbon is deposited in the form of a very fine black powder of extreme lightness. This black is used in making the better qualities of printers' ink.

BLACKING FOR SHOES. (*Cirage des bottes*, Fr.; *Schuhschwärze.*)

The following prescription for making liquid and paste blacking is given by William Bryant and Edward James, under the title of a patent, dated December, 1836. Their improvement consists in the introduction of caoutchouc, with the view, possibly, of making the blacking waterproof:—

18 ounces of caoutchouc are to be dissolved in about 9 pounds of hot rape oil. To this solution 60 pounds of fine ivory black, and 45 pounds of molasses, are to be added, along with 1 pound of finely ground gum arabic, previously dissolved in 20 gallons of vinegar, of strength No. 24. These mixed ingredients are to be finely triturated in a paint mill till the mixture becomes perfectly smooth. To this varnish 12 pounds of sulphuric acid are to be now added in small successive quantities, with powerful stirring for half an hour. The blacking thus compounded is allowed to stand for 14 days, it being stirred half an hour daily; at the end of which time, 3 pounds of finely-ground gum arabic are added; after which the stirring is repeated half an hour every day for 14 days longer, when the liquid blacking is ready for use.

In making the paste blacking, the patentees prescribe the above quantity of India rubber oil, ivory black, molasses, and gum arabic, the latter being dissolved in only 12 pounds of vinegar. These ingredients are to be well mixed, and then ground together in a mill till they form a perfectly smooth paste. To this paste 12 pounds of sulphuric acid are to be added in small quautities at a time, with powerful stirring, which is to be continued for half an hour after the last portion of the acid has been introduced. This paste will be found fit for use in about 7 days.

BLACK SILK DYEING. In dyeing silk, "*the hat-black color,*" it has been usual to employ nitrate of iron as a mordant, and oak bark as the dye stuff, but Mr. Le Leivre has found that alder bark is preferable; in the next process fustic has been employed, but equal parts of fustic and citron bark are to be preferred; and the patentee proposes to finish the process with a lather of olive oil, soap and logwood.

In stretching silk so dyed he does it in an atmosphere of steam, by placing a perforated tube connected with a steam boiler close under the silk while being stretched.

BLEACHING (*Blanchiment*, Fr.; *Bleichen*, Germ.) is the process by which the textile filaments, cotton, flax, hemp, wool, silk, and the cloths made of them, as well as various vegetable and animal substances, are deprived of their natural color, and rendered nearly or altogether white. The term bleaching comes from the French verb *blanchir*, to whiten. The word *blanch*, which has the same origin, is applied to the whitening of living plants by making them grow in the dark, as when the stems of celery are covered over with mould.

The operations which the bleacher has recourse to differ according to the nature of the bleaching means, the property of the stuff to be bleached, and local customs or circumstances; and the result is also obtained with more or less rapidity, certainty, economy, and perfection. The destruction of the coloring matters attached to the bodies to be bleached is effected either by the action of the air and light, of chlorine, or sulphurous acid; which may be considered the three bleaching powers employed for manufacturing purposes.

Bleaching by the influence of air and sunshine is the most ancient, and still the most common, method in several civilized countries; it is also supposed by many to be the least injurious to the texture of yarn and cloth. The operations it involves are very simple, consisting in the exposure of the goods upon a grass-plat to the sky, with their occasional aspersion with moisture if necessary, in addition to the rain and dew. The atmospheric air effects the bleaching by means of its oxygenous constituent, which combines with the coloring matter, or its elements carbon and hydrogen, and either makes it nearly white, or converts it into a substance easily soluble in water and alkaline solutions. This natural process is too slow to suit the modern demands of the cotton and linen manufacturers. Fortunately for them, a new bleaching agent, unknown to our forefathers, has been discovered in chlorine, formerly called oxymuriatic acid, an agent modified by chemistry so as to give an astonishing degree of rapidity, economy, and perfection, to this important art. It is, however, not a little surprising, that the science which has so greatly advanced its practical part should have left its theory far from complete, and should afford no satisfactory answers to the two following questions.—What is the action of the solar rays upon the coloring matter? How do air and chlorine operate upon this principle? Some suppose that light *predisposes* the coloring matter to combine with oxygen; others fancy that it acts merely in the manner of a high temperature, so as to determine a reaction between the elements of that substance, and to cause a new combination possessed of peculiar properties. It is generally admitted at the present day, that a portion of the oxygen of the air passes into the coloring matter, and changes its constitution. This is, however, probably not the part which oxygen plays, nor is it the only principle in the atmosphere which exercises a bleaching influence. Neither is the action of chlorine such as has been commonly represented in our chemical systems.

But if authors offer us only vague hypotheses concerning the three principal agents, light, oxygen, chlorine, they afford no information whatever concerning the phenomena due to greasy spots so frequently found upon cotton cloth, and so very troublesome to the bleacher. It has indeed been sometimes said in bleach-works, that fatty substances are no longer soluble in alkalis, when they are combined with oxygen. The very reverse of this statement is probably nearer the truth.

The object of bleaching is to separate from the textile fibre, by suitable operations, all the substances which mask its intrinsic whiteness: or which, in the course of ulterior dyeing operations, may produce injurious effects. In this latter respect, cotton deserves especial consideration. This substance is covered with a resinous matter, which obstructs its absorption of moisture, and with a yellow coloring matter in very small quantity, often so inconsiderable in some cottons, that it would be unnecessary to bleach them, before submitting them to the dyer, were it not that the manipulations which they undergo introduce certain impurities which are more or less injurious, and must be removed. It is in fact a circumstance well known in the factories, that unbleached cottons may be dyed any dark color, provided they are deprived of that matter which makes them difficult to moisten. The substances present in cotton goods are the following:—

1. The resinous matter natural to the cotton filaments.
2. The proper coloring matter of this vegetable.
3. The paste of the weaver.
4. A fat matter.
5. A cupreous soap.
6. A calcareous soap.
7. The filth of the hands.
8. Iron, and some earthy substances.

1. The matter which prevents the moistening of cotton wool may be separated by means of alcohol, which, when evaporated, leaves thin yellowish scales, soluble in alkalis, in acids, and even in a large quantity of boiling water. For a long time the bleaching process commenced with the removal of this resinous stuff, by passing the cloth or the yarn through an alkaline ley. This was called scouring; it is now nearly laid aside.

2. The coloring matter of cotton seems to be superficial, and to have no influence on the strength of the fibres; for the yarn is found to be as strong after it has been stripped by caustic soda of its resinous and coloring matters, as it was before. The coloring matter is slightly soluble in water, and perfectly in alkaline leys. When gray calico is boiled in lime-water, it comes out with a tint darker than it had before; whence it might be supposed that the coloring matter was not dissolved out, even in part. This, however, is not the case; for if we filter the liquor, and neutralize it with an acid, we shall perceive light flocks, formed of the resinous substance, united with the coloring matter. The dark color of the cloth is to be ascribed solely to the property which lime possesses of browning certain vegetable colors. This action is here exercised upon the remaining color of the cloth.

It may be laid down as a principle, that the coloring matter is not directly soluble by the alkalis; but that it becomes so only after having been for some time exposed to the joint action of air and light, or after having been in contact with chlorine. What change does it thereby experience, which gives it this solubility? Experiments made upon pieces of cloth placed in humid oxygen, in dry oxygen, in moist chlorine, and in dry chlorine, tend to show that hydrogen is abstracted by the atmosphere; for in these experiments proofs of *dis-hydrogenation* appeared, and of the production of carbonic acid. In all cases of bleaching by chlorine, this principle combines immediately with the hydrogen of the coloring matter, and forms muriatic acid, while the carbon is eliminated. Undoubtedly water has an influence upon this phenomenon, since the bleaching process is quicker with the humid chlorine than with the dry; but this liquid seems to act here only mechanically, in condensing the particles of the gas into a solution. We should also take into account the great affinity of muriatic acid for water.

3. The weaver's dressing is composed of farinaceous matters, which are usually allowed to sour before they are employed. It may contain glue, starch, gluten; which last is very soluble in lime-water.

4. When the dressing gets dry, the hand-weaver occasionally renders his warp-threads more pliant by rubbing some cheap kind of grease upon them. Hence it happens, that the cloth which has not been completely freed from this fatty matter will not readily imbibe water in the different bleaching operations; and hence, in the subsequent dyeing or dunging, these greasy spots, under peculiar circumstances, somewhat like lithographic stones, strongly attract the aluminous and iron mordants, as well as the dye-stuffs, and

occasion stains which it is almost impossible to discharge. The acids act differently upon the fatty matters, and thence remarkable anomalies in bleaching take place. When oil is treated with the acetic or muriatic acid, or with aqueous chlorine, it evolves no gas, as it does with the sulphuric and nitric acids, but it combines with these substances so as to form a compound which cannot be dissolved by a strong boiling ley of caustic soda. Carbonic acid acts in the same way with oil. On the other hand, when the oils and fats are sufficiently exposed to the air, they seize a portion of its oxygen, and become thereby capable of saponification, that is, very soluble in the alkalis.

5. When the hand-weaver's grease continues in contact for a night with the copper dents of his reed, a kind of cupreous soap is formed, which is sometimes very difficult to remove from the web. Lime-water does not dissolve it; but dilute sulphuric acid carries off the metallic oxyde, and liberates the margaric acid, in a state ready to be acted on by alkalis.

6. When cloth is boiled with milk of lime, the grease which is uncombined unites with that alkaline earth; and forms a calcareous soap, pretty soluble in a great excess of lime-water, and still more so in caustic soda. But all fats and oils, as well as the soaps of copper and lime, cease to be soluble in alkaline leys, when they have remained a considerable time upon the goods, and have been in contact with acetic, carbonic, muriatic acids, or chlorine. These results have been verified by experiment.

7. Cotton goods are sometimes much soiled, from being sewed or tamboured with dirty hands; but they may be easily cleansed from this filth by hot water.

8. Any ferruginous or earthy matters which get attached to the goods in the course of bleaching, are readily removable.

We are now prepared to understand the true principles of bleaching cotton goods, for the most delicate operations of the calico printer.

1. The first process is steeping, or rather boiling, the goods in water, in order to remove all the substances soluble in that liquid.

2. The next step is to wash or scour the goods by the dash-wheel or the stocks. This is of great importance in the course of bleaching, and must be repeated several times; so much so, that in winter, when the water of the dash-wheel is cold, the bleaching is more tedious and difficult. Yarn and very open fabrics do not much need the dash-wheel.

By these first two operations, the woven goods lose about sixteen per cent. of their weight, while they lose only two parts out of five hundred in all the rest of the bleaching.

3. In the third place the calicoes are boiled with milk of lime, whereby they are stripped of their gluten, and acquire a portion of calcareous soap. Formerly, and still in many bleach-works, the gluten was got rid of by a species of fermentation of the farinaceous dressing; but this method is liable to several objections in reference to the calico printer. 1. The fermentative action extends sometimes to the goods and weakens their texture, especially when they are piled up in a great heap without being previously washed. 2. The spots of grease, or of the insoluble soaps, become thereby capable of resisting the caustic alkalis, and are rendered in some measure indelible; an effect due to the acetic and carbonic acids generated during fermentation, and which will be easily understood from what has been said concerning the action of acids on fatty substances. It is not, therefore, without good reason that many practical men throw some spent leys into the fermenting vats, to neutralize the acids which are formed. Were it not for the presence of fat, fermentation, skilfully conducted, would be an excellent means of carrying off the gluten; and the steep is therefore applicable to power-loom goods, which are not polluted with grease.

4. The goods are now subjected to a caustic soda ley, which dissolves out the soaps of lime and copper, as well as that portion of the coloring matter which is sufficiently dis-hydrogenated to be capable of combining with it. This bucking with ley, which is repeated several times upon the goods, in order to purge them completely from the fatty matter present in the hand-loom webs, and also partially introduced in the spinning, is almost the only operation to which yarns for Turkey red are subjected. After being boiled in a caustic soda ley, they are passed through solutions of chloride of lime, and afterwards through the acid steep.

5. When the goods are sufficiently bucked in the leys, they are either exposed to chlorine, or laid out on the grass; sometimes both are had recourse to for delicate work. These different modes of action have the same influence on the coloring matter, but they give rise to different effects in reference to greasy stains.

The goods are dipped in a solution of chloride of lime, which should be kept tepid by means of steam. Alongside of the chlorine cistern, there is another filled with dilute sulphuric or muriatic acid. When the goods are taken out of the chlorine, they are drained on the top of its cistern till no more liquid runs off them, and they are then plunged into the *sour*. The action of the acid in the present case may be easily explained. In proportion as a salt of lime is formed, this base quits the chlorine, and allows it to act freely upon the coloring matter. Thus we prevent the development of too great a quantity of chlorine at once, which would be apt to injure the fibres; and we pursue both a prudent and economical plan. Only so much chlorine as is strictly necessary is called forth, and hence it excites no smell in the apartment.

The chlorine serves to acidify the coloring matter, by abstracting a portion of its hydrogen; but we must take the greatest care that there is no grease upon the goods before immersion in it, for the consequence would be, as above shown, very troublesome spots. When the cloth is laid out upon the grass, it is the oxygen of the air which acidifies the coloring matter; for which reason, the dew, which contains much air rich in oxygen, singularly accelerates the bleaching process. It is likewise, by absorbing oxygen from the atmosphere, that fats or oils pass to the state of margaric and oleic acids, and become most easily saponified. Should the goods, however, be left too long on the grass, the fats absorb carbonic acid, and become insoluble in leys.

6. The goods must now receive a new soda ley, to dissolve out that portion of the coloring matter which has been dis-hydrogenated in the chlorine of the air, as well as the grease, if any perchance remained in the soluble state. These last two operations are to be several times repeated, because the coloring matter should be removed only by degrees, for fear of injuring the texture of the goods, by subjecting them to too much chlorine at a time.

7. We finish with the dilute sulphuric acid, which should be very weak and tepid. It dissolves out the iron, and some earthy matters occasionally found upon cotton. The goods must be most carefully washed at the dash-wheel, or in a stream of water on quitting the sour bath, for if the acid were allowed to dry in them, it would infallibly injure their texture by its concentration. In winter, if the goods are allowed to get frozen with the acid upon them, they may likewise be damaged.

We may here observe, that when the goods are not to remain white, their bleaching may be completed with a ley; for though it leaves a faint yellow tint, this is no inconvenience to the dyer. But when they are to be finished with a starching after the last ley, they must have another dip of the chlorine to render the white more perfect. An immersion in the dilute acid has nearly the same effect.

The principles expounded above lead to this important consequence, that when we wish to bleach goods that are free from greasy stains, as is the case generally with the better kinds of muslins, or when we wish to bleach even greasy goods for the starch finish, we may content ourselves with the following operations:—

1. Boiling in water.
2. Scouring by the stocks or the dash-wheel.
3. Bucking with milk of lime.
4. Passing through chlorine, or exposure on the grass.
5. Bucking, or bouking with milk of lime. These two latter operations require to be alternated several times, till the whole of the coloring matter be removed.
6. Souring.

The bleaching of goods, which are never laid down on the green, and which are not dried between two operations, may be completed in a couple of days. They answer as well for the printer as the others, and they are as white. Cotton fibres or yarns suffer no diminution of their strength, when the cloth has been properly treated in the above described processes.

Accurate experiments have demonstrated that their strength is not impaired by being boiled in milk of lime for two hours at the ordinary pressure, provided they be constantly kept covered with liquid during the whole ebullition, and that they be well washed immediately afterwards; or, by being boiled in pure water under the pressure of ten atmospheres of steam; or by being boiled under the same pressure in a caustic soda ley, marking 3° of Tweedale, or specific gravity 1·015, though it has increased to double the density in the course of the boil, by the escape of the steam; or by being boiled under the atmospheric pressure at 14° of Tweedale, or specific gravity of 1·070; or by being immersed for eight hours in chloride of lime, capable of decoloring three times its bulk, of test solution of indigo (See Chlorine); and by being afterwards dipped in sulphuric acid of specific gravity 1·067, Tweedale 14°; or by being steeped for eighteen hours in sulphuric or muriatic acid of specific gravity 1·035, 7° Tweedale.

In other well-conducted bleach-works the following is the train of operations:— 1. Cleansing out the weaver's dressing by steeping the cloth for twelve hours in cold water, and then washing it at the stocks or the dash-wheel. 2. Boiling in milk of lime, of a strength suited to the quality of the goods, but for a shorter time than with the soda ley; two short operations with the lime, with intermediate washing, being preferable to one of greater duration. 3 and 4. Two consecutive leys of ten or twelve hours' boiling, with about two pounds of soda chrystals for 1 cwt. of cloth. 5. Exposure to the air for six or eight days, or the application of the chloride of lime and the sulphuric acid. 6. A ley of caustic soda, like the former, sometimes with less alkali. 7. Exposure to the air for six or eight days, or chlorine and the sour, as above. 8. Caustic soda ley, as before. 9. Chlorine and the sour. 10. Rinsing in hot water, or scouring at the dash-wheel.

If the number of vessels to be heated exceeds four or five, there is an economy in using steam as the medium of heat; but under this number there is an advantage in the direct application of fire to a boiling or bucking apparatus; since when only two vessels are in activity, there is a waste of fuel by the extra steam power. It deserves to be remarked, also, that the increase of the bulk of the liquid by the condensation of the steam, does not permit the spent white ley to be turned to use for the green goods, on account of its excessive dilution. With the milk of lime boil, however, this dilution would be rather an advantage.

It has been found that the introduction of bran into the fermenting steep (when this is used) endangers the texture of the goods, by causing a putrefactive fermentation in some places.

When in the milk of lime boil there is too much of this caustic earth, or when it is poured in on the top of the goods, they are apt to suffer damage. The milk of lime should be introduced from beneath into the under compartment of the bucking apparatus. For the same reason, after the caustic soda ley, the vessel should be filled up with water, if the goods be not immediately transferred to the dash-wheel. When they are allowed to become partially dry on the top, they are easily injured. The copper of the bucking apparatus ought to be of a size proportioned to that of the surmounting crib or vat; for when it is too small, the liquid is too long of being brought into proper circulation, and the goods may be meanwhile injured. In a bucking apparatus, which requires five or six hours to be brought into full play, those goods are very apt to be injured, which lie immediately under the overflow pipe.

When the chloride of lime steep is too strong, sometimes small round holes are made in the calico, just as if they had been cut out by a punch, especially in the borders or thicker parts of the goods. This accident is owing to the presence of bubbles of chlorine. From the saturated state of the liquid, they remain gaseous a sufficient length of time for corroding the parts of the cloth with which they are in contact. These will be obviously the denser parts, for they confine the gas most completely, or prevent its diffusion through the mass. This evil is prevented by diluting the chloride steep to the proper degree, and moving the goods through it.

The greasy spots, described above, show themselves in the maddering by attracting the dye-stuff more copiously than the pure parts of the cloth, so as to mottle it; they are also recognised in the white goods by being somewhat repulsive of moisture. When the combination of fatty matters with chlorine takes place at the surface of cotton goods, it is of a nature to resist the action of alkalis. It is the stearine, or the principle of suet, particularly, which, by this means, acquires such a strong affinity for cottons; the elaine, or the principle of oils, has no such remarkable affinity. Lime, in some circumstances, seems to act as a mordant to greasy matters, and to fix them fast. Hence the weaver should be prohibited, in all cases, from allowing candle-grease to touch his web. Goods soiled with it should never be allowed to lie by in the ware-house, but be immediately cleansed before the air has fixed the stearine by converting it into margaric acid. Lime should, in these cases, be prudently employed; chlorine should never be used till the greasy stains are thoroughly removed; and the bleacher should never warrant his pieces for the printer till he has verified some of them by the water test.

I shall conclude this general analysis of the principles of bleaching by a few precepts. Avoid lime, at the first ley, for goods which contain greasy spots; but use it freely after one or two soda leys, and apply two soda leys after it. Do not apply chlorine between these leys, but reserve it for the final operation. By this plan the goods will be well bleached and very little worn. Use the souring steeps freely, giving them after each ley, whether of lime or soda, since the calcareous base, with which the greasy spots get charged merely from hard water, is an obstacle to the further action of the leys.

I shall now give some practical instructions concerning the several steps of the bleaching process, as applied to cotton, linen, silk, and wool.

The first thing which the cotton bleacher does, is to mark the pieces with the initials of the owner, by means of a stamp imbued with coal tar. The linen bleacher marks with nitrate of silver, a far more expensive substance, but one which resists better the severer treatment which his goods are destined to undergo.

The cotton goods are generally singed before they are sent to the bleacher, and this is done either by passing them rapidly over a red-hot semi-cylinder of iron, or over a row of gas flames, by Mr. Hall's ingenious contrivance. (See Singeing.) Each piece is next creased together lengthwise like a rope, folded into a bundle, and fixed by a noose at the end. In this open state it is easily penetrated by the water of the soaking cistern into which it is thrown. It is then scoured by the dash or wash-wheel. It is now ready for

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the bucking or steaming apparatus, where it is treated with milk of lime. The steam chamber resembles the bucking vessel, without its bottom copper; that is to say, a few inches below the grated bottom of the bucking tub, there is a close iron sole, through the centre of which the steam is admitted by several small apertures, for the purpose of diffusing it throughout the goods, and causing a liquid circulation by its pressure, as the steam does in the proper bucking boiler. One pound of lime previously made into a cream consistenced mixture, and passed through a sieve, is used for every thirty or forty pounds of cloth, according to its color and texture; and this cream mixed with more water is interstratified with the pieces, as they are laid regularly in the vessel. Whenever this is stocked with goods, all their interstices are filled up with water. After the lime bucking, the cloth is transferred to the dash-wheel.

A pound of cloth requires for its whitening about half a pound of good average chloride of lime or bleaching powder, as it is commonly called, and this ought to be dissolved in about three gallons of water. Mr. Crum of Thorniebank, near Glasgow an extensive and excellent bleacher, has so modified Dr. Dalton's ingenious plan of testing the power of bleaching liquors by green sulphate of iron, as to give it much greater precision for the bleacher's use, than the discoloration of indigo originally proposed by Berthollet. Mr. Crum dissolves four ounces of fresh green vitriol in hot water, and then adds the solution of bleaching powder by small quantities at a time, till the iron becomes wholly peroxydized, when the smell of chlorine will become perceptible. When the bleacher has once found by trial the proper blanching power which his chlorine steep ought to have, he can verify its standard, by seeing how much of it must be added to an ounce, or any given weight of fresh copperas, dissolved in hot water, to cause the peroxydizement and the exhalation of the peculiar odor. M. Gay Lussac's new method by arsenious acid will be described under chlorine. From the experiments which I made some years ago,* upon indigo, it will be seen that this dye stuff is so variable in its quantity of coloring matter, that no two chemists operating with it independently, as a test for chloride of lime, could arrive at the same result. They must provide themselves with absolute indigo, by an expensive and troublesome process, not suited to the busy bleacher. The vitriolage, as the French term it, or the souring of the English bleacher, consists in immersing the goods for four hours in dilute sulphuric acid, containing one gallon of oil of vitriol to from 25 to 30 of water, thoroughly intermixed by stirring; for the density of the acid is an obstacle to its equal distribution through the water. This dilute acid will have a density of from 1·047 to 1·040, and will contain from 7 to 6½ per cent. by weight of the oil of vitriol.

The goods are now washed, and then boiled for eight or nine hours in an alkaline ley, containing about two pounds of crystals of soda, or their equivalent in soda ash or pearl-ash, for every 100 lbs. of cloth. The ley must be made previously caustic by quick lime. A washing in the wheel follows this boil; and then a chlorine steep for five hours in a liquor two thirds of the strength of the former. It is next soured in the dilute sulphuric acid, for two, three, or four hours, according to the color and quality of the cotton, and then thoroughly washed.

The cloth is now bleached white, but cannot be presented in the market till it undergoes certain finishing processes. The piece is elongated from the folds which it contracts during the rotation of the dash-wheel by being thrown into a stream of water in a cistern, terminated by the squeezing rollers, which take in the end of the piece, and run it through between them, with the effect of making it nearly dry. Two pieces of cloth pass simultaneously through the rollers, and are disentangled spontaneously, so to speak, without the help of hands.

The squeezing rollers or squeezers, for discharging the greater part of the water from the yarns and goods in the process of bleaching, are represented in *figs.* 130, 131, the

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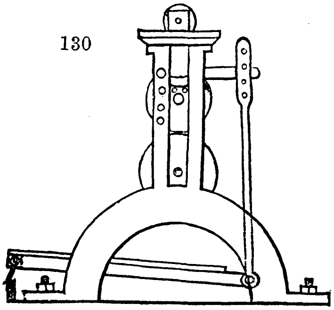

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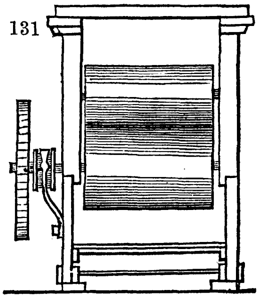

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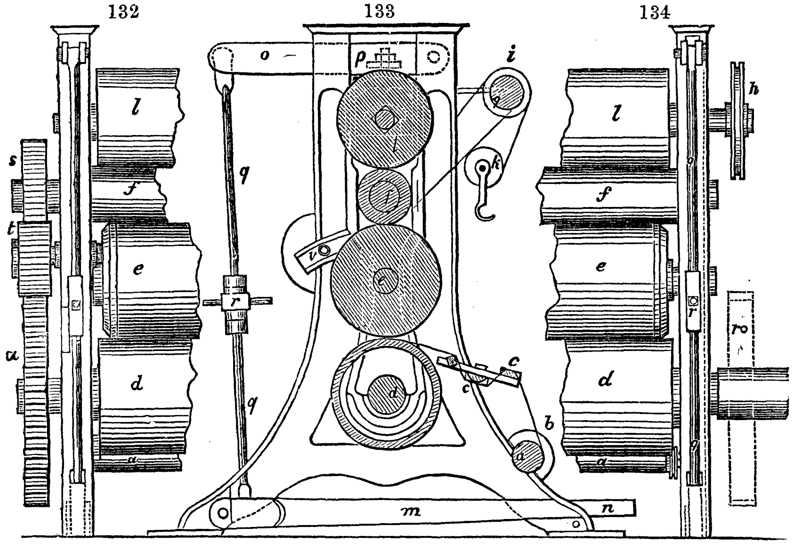
* Quarterly Journal of Science, Literature, and the Arts, vol. vii. p. 160

former being a side-view, to show how the roller gudgeons lie in the slots of the frame, and how the shaft of the upper roller is pressed downward by a weighted lever, through a vertical junction rod, jointed at the bottom to a nearly horizontal bar, on whose end the proper weight is hung. In *fig.* 131 these rollers of birch-wood are shown in face; the under one receiving motion through the toothed wheel on its shaft, from any suitable power of water or steam. Upon the shaft of the latter, between the toothed wheel and the roller, the lever and pulley for putting the machine into and out of gear are visible. The under roller makes about 25 revolutions in the minute, in which time three pieces of goods, stitched endwise, measuring 28 yards each, may be run through the machine, from a water trough on one side, to a wooden grating upon the other.

When the goods are run through, they are carried off upon a grated wheelbarrow, in a nearly dry state, and transferred to the spreading machine, called at Manchester a *candroy*. In many bleach-works, however, the creased pieces are pulled straight by the hands of women, and are then strongly beat against a wooden stock to smooth out the edges. This being done, a number of pieces are stitched endwise together, preparatory to being mangled.

Calender.—*Fig.* 133 is a cross section of this machine, and *figs.* 132, 134, are front views broken off. The goods are first rolled upon the wooden cylinder *a*, near the ground; by the tension roller *b*, upon the same cylinder, the goods receive a proper degree of stretching in the winding off. They then pass over the spreading bars *c c c*, by which they are still more distended; next round the hollow iron cylinder *d*, 16 inches diameter, and the paper cylinder *e*, of like dimensions; thence they proceed under the second massive iron cylinder *f*, of 8 inches diameter, to be finally wound about the projecting wooden roller *g*. This is set in motion by the pulleys *h*, *fig.* 134, and *i*, *fig.* 133, and receives its proper tension from the hanging roller *k*; *l* is a press cylinder, of 14 inches diameter, made of plane-tree wood. By its means we can at all times secure an equal degree of pressure, which would be hardly possible did the weighted lever press immediately upon two points of the calender rollers. The compression exercised by the cylinders may be increased at pleasure by the bent lever *m*, weights being applied to it at *n*. The upper branch of the lever *o* is made fast by screws and bolts at *p*, to the upper press-cylinder. The junction leg *q* is attached to the intermediate piece *r*, by left and right-handed screws, so that according as that piece is turned round to the right or the left, the pressure of the weighted roller will be either increased or diminished. By turning it still more, the piece will get detached, the whole pressure will be removed, and the press-roller may be taken off; which is a main object of this mechanism.

132 133 134



The unequable movement of the cylinders is produced by the wheels *s t u*, of which the undermost has 69, the uppermost has 20, and the carrier-wheel *t*, either 33, 32, or 20 teeth, according to the difference of speed required. The carrier-wheel is bolted on at *v*, and adjusted in its proper place by means of a slot. To the undermost iron cylinder, the first motion is communicated by any power, for which purpose either a rigger (driving pulley) is applied to its shaft at *u*, or a crank motion. If it be desired to operate with a heated calender, the undermost hollow cylinder may be filled with hot steam, admitted through a stuffing-box at one end, and discharged through a stuffing-box at the other, or by a red-hot iron roller.

Pure starch would be too expensive a dressing for common calico shirtings, and therefore an extemporaneous starch is made by mixing one pound of flour with one gallon of water, and allowing the mixture to ferment in a warm place for twenty-four hours. In this way, a portion of *lactic* acid is formed, which dissolves the gluten, or separates it from the starch; so that when the whole is thrown upon a sieve, a liquid paste passes through, which, being boiled, answers well for stiffening the goods, without giving them a gray tinge. The paste is thinned with water to the desired degree, and faintly tinged with solution of indigo. The starch, which is sometimes thickened with porcelain clay, Paris plaster, or Spanish white, is put into a trough, and is evenly imparted to the cloth as this is drawn down through it, by the traction of rollers. There is a roller near the bottom of the trough, round which the cloth is made to run, to secure its full impregnation; while the upper rollers serve to expel its excess of the starch, and throw it back into the cistern. See STARCHING APPARATUS.

The goods are next dried in an apartment heated by two, three, or more flues, running along the floor, and covered usually with fire-tiles. At first the heat is moderate, but it is gradually raised to upwards of 110° F.

The goods must now be passed again through the calender, in order to receive their final smoothness and lustre. They are, in the first place, damped with a peculiar machine, furnished with a circular brush, whose points revolve in contact with water in a trough placed beneath them, and sprinkle drops of water upon the goods as they are drawn forward by a pair of cylinders. They are then subjected to the powerful pressure of the calender rollers.

The calendered pieces are neatly folded into compact parcels, and stamped with the marks of each particular manufacturer, or various devices to suit the markets for which they are designed. They are finally piled on the sole of an hydraulic press, with a sheet of pasteboard between each piece; but with occasional plates of iron to secure uniformity of pressure throughout. When sufficiently condensed by the press, they are taken out, and despatched to their respective manufacturers in a state ready for sale.

There are no less than 25 steps in the bleaching of calicoes, many of them effected with expensive machinery; yet the whole do not produce to the bleacher more than 10 pence per piece of 24 yards.

The following system was pursued, a few years back, by a skilful bleacher of muslins near Glasgow:—

"In fermenting muslin goods, we surround them with our spent leys, from the temperature of 100° to 150° F., according to the weather, and allow them to ferment for 36 hours. In boiling 112 lbs. = 112 pieces of yard-wide muslin, we use 6 or 7 lbs. of pearl-ashes, and 2 lbs. of soft soap, with 360 gallons of water, and allow them to boil for 6 hours; then wash them, and boil them again with 5 lbs. of pearl-ashes and 2 lbs. of soft soap, and allow them to boil 3 hours; then wash them with water, and immerse them into the solution of oxymuriate of lime, at 5 on the test-tube, and allow them to remain from 6 to 12 hours; next wash them, and immerse them into dilute sulphuric acid at the specific gravity of 3½ on Tweedale's hydrometer = 1·0175, and allow them to remain an hour. They are now well washed, and boiled with 2½ lbs. of pearl-ashes, and 2 lbs. of soft soap for half an hour; afterwards washed and immersed into the oxymuriate of lime as before, at the strength of 3 on the test-tube, which is stronger than the former, and allowed to remain for 6 hours. They are again washed, and immersed in diluted sulphuric acid at the specific gravity of 3 on Tweedale's hydrometer = 1·015. If the goods be strong, they will require another boil, steep, and sour. At any rate, the sulphuric acid must be well washed out before they receive the finishing operation with starch.

"With regard to the lime, which some use instead of alkali immediately after fermenting, the same weight of it is employed as of pearl-ashes. The goods are allowed to boil in it for 15 minutes, but no longer, otherwise the lime will injure the fabric."

More recently the plan adopted is as follows; by which the purest whites are produced for the London market.

"Lime is seldom used for our finer muslin goods, as it is found to injure their fabric, and the colors do not keep for any length of time.

"An alkaline ley is made by boiling equal weights of lime and soda together for an hour: this alkali is used for boiling goods the same as potash, but without soap.

"In finishing jaconets or muslins, after washing them from the sour, they are run through spring-water containing a little fine smalts, which give them a clear shade; if of a coarse fabric, a little well-boiled starch is added to the water. From this they are wrung or pressed, and taken up by the selvage for the breadthing frame, and are run off it upon a tin cylinder heated by steam, by which the piece is completely dried in 15 minutes: it is then stripped from the cylinder, neatly folded and pressed, which finishes the piece for the market. From 6*d.* to 9*d.* per piece of 12 yards is obtained for the bleaching and finishing of those goods.

"Book muslins, after being washed from the sour, are wrung or pressed; then they are hung up to dry in a heated stove, previous to being put into starch, prepared by boiling 3 lbs. of it to every 5 gallons of water, with 20 ounces of smalts: they are wrung out of this starch, and taken to a room heated to 110° F.; the starch is wrought into the piece till clear, then taken into a cold room, and the selvages dressed or set, before being put on the breadthing frame in the heated stove, where the piece is stretched to its length, while three or four persons at each selvage keep the piece to its breadth. If a stiff finish is wanted, they keep exactly opposite each other; but in breadthing the piece of elastic, they cross the piece in breadthing, which gives it a springy elastic finish. From 9*d.* to 15*d.* per piece of 12 yards is obtained for the bleaching and finishing of these goods.

"Sewed trimmings, flounces, and dresses are run through spring water containing fine smalts with a little well-boiled starch. They are then taken to the drying-stove, where they are stented till dry, which finishes the piece for the market. From 6*d.* to 8*d.* per piece is obtained for trimmings and flounces, and from 9*d.* to 1*s.* for dresses, bleaching and finishing."

In the bleaching of cotton cloth, where fixed colors are previously dyed in the yarn before it is woven into cloth, such as the Turkey or Adrianople red, and its compounds of lilach or purple, by the addition of iron bases, various shades of blue from indigo, together with buff and gold color, tinged with the oxydes of iron, great care is necessary.

The common process of bleaching pulicates, into which permanent colors are woven, is, to wash the dressing or starch well out in cold water; to boil them gently in soap, and, after again washing, to immerse them in a moderately strong solution of the oxymuriate of potash; and this process is followed until the white is good: they are then soured in dilute sulphuric acid. If the goods are attended to in a proper manner, the colors, in place of being impaired, will be found greatly improved, and to have acquired a delicacy of tint which no other process can impart to them.

Pulicates, or ginghams, which have been woven along with yarn which has been previously bleached, are first freed by washing from the starch or dressing: they are then washed, or slightly boiled with soap. After which, they are completely rinsed in pure spring water, and then soured.

Besides these common processes for bleaching, another was some time ago introduced, which consisted in immersing the cotton or linen goods in pretty strong solution of caustic alkali, and afterwards exposing them to the action of steam in a close vessel. It is now generally abandoned.

The cotton or linen goods, having been previously cleaned by steeping and washing, were, after being well drained, steeped in a solution of caustic alkali of the specific gravity of 1020. After the superfluous alkaline ley had been drained from them, they were arranged on a grating in a receiver. The cover was then placed on the vessel, and firmly screwed down; and the steam was admitted by turning the stopcock of the pipe which communicated with a steam boiler of the common construction.

The stains which come out upon maddered goods, in consequence of defective bleaching, are called in this country *spangs*. Their origin is such as I have described above, as the following statement of facts will show. The weaver of calicoes receives frequently a fine warp so tender from bad spinning or bad staple in the cotton, that it will not bear the ordinary strain of the heddles, or friction of the shuttle and reed, and he is obliged to throw in as much weft as will compensate for the weakness or thinness of the warp, and make a good marketable cloth. He of course tries to gain his end at the least expense of time and labor. Hence, when his paste dressing becomes dry and stiff, he has recourse to such greasy lubricants as he can most cheaply procure; which are commonly either tallow or butter in a rancid state, but the former, being the lowest priced, is preferred. Accordingly, the weaver, having heated a lump of iron, applies it to a piece of tallow held over the warp in the loom, and causes the melted fat to drop in patches upon the yarns, which he afterwards spreads more evenly by his brush. It is obvious, however, that the grease must be very irregularly applied in this way, and be particularly thick on certain spots. This irregularity seldom fails to appear when the goods are bleached or dyed by the common routine of work. Printed calicoes examined by a skilful eye will be often seen to be stained with large blotches evidently occasioned by this vile practice of the weaver. The ordinary workmen call these *copper* stains, believing them to be communicated in the dyeing copper. Such stains on the cloth are extremely injurious in dyeing with the indigo vat. The following plan is adopted by some Scotch bleachers, with the effect, it is said, of effectually counteracting spangs from grease.

The goods having been singed and steeped in pure water, as is customary in common bleaching, they are passed through a pair of rollers to press out the impurities which have been loosened by the steeping. It must here, however, be observed, that where the expense of one extra drying can be afforded, the process might be very much improved by steeping the brown calicoes for thirty or forty hours before singeing, because this would separate much of that impurity which usually becomes fixed in the stuff on its being passed over the hot cylinders. When the pieces have been thus singed, steeped, and pressed, they are boiled four times, ten or twelve hours at each time, in a solution of caustic potash, of the specific gravity of from 1·0127 to 1·0156, washing them carefully and thoroughly in pure water between each of these boilings. They are then immersed in a solution of the chloride of potash, originally of the strength of 1·0625, and afterwards reduced with twenty-four times its measure with water.

When the preparation is good, these proportions will whiten cotton goods completely in eight hours. In this steep they are, however, generally suffered to remain twelve hours. It has been supposed that the common bleaching liquor (chloride of lime) cannot, without injury, be substituted for chloride of potash, but I believe this to be a mistake.

Some printers take the pieces from this solution, and, while wet, lay them upon the grass, and there expose them to the sun and weather for two or three days. They are thence removed to the sours, made of the specific gravity of about 1·0254 at the temperature of 110° of Fahrenheit. In bleaching common goods, and such as are not designed for the best printing, the specific gravity of the sours is varied from that of 1·0146 to that of 1·0238, if weighed when they become of the temperature of the atmosphere. In these they are suffered to lie for five or six hours, after which they are taken to the dash-wheel and washed thoroughly. When this operation is finished, they are submitted to four more boilings as before, with a solution of caustic potash; taking care to wash well between each of these boilings. Sometimes pearl-ash, made caustic, is used for the last of these boilings, lest the sulphur, which always exists in the potashes of commerce, should impair the whites. They are next immersed in the diluted chloride of potash, of the strength before mentioned; after which they are well washed in pure water, and then winched for half an hour in common sours. The last process is that of careful washing in plenty of clean water, after which they are not put into the stove, but are immediately hung up in the airing sheds to dry gradually. The water must be good, and abundant.

The number of operations, as here described, is great; but I know of no other mode of procedure by which perfect bleaching is so likely to be effected at all times and in all seasons, without disappointment. It must here be remarked, that, for the best purposes of printing, it would not be sufficient to take goods which have been bleached in the common way and finish these by the better process; because the sulphate of lime deposited in the cloth by that operation will be apt to spoil them for madder colors; at least, a printer who is curious in his business would hesitate to work up such cloth.

Bucking or Bowking.—This is one of the most important operations in the bleaching of both cotton and linen goods. There are several methods whereby this process is carried on; but of these we shall select only two, distinguishing them as the old and new method of bucking. In the former way, the cloths have been steeped in the alkaline ley, as before described, and afterwards well washed, are regularly arranged in a large wooden vat, or kieve; a boiler of sufficient capacity is then filled with caustic alkaline ley, which is heated to the temperature of blood. The boiler is then emptied by a stop-cock upon the linens in the kieve, until they are covered with the liquor. After having remained on the cloth for some time, it is run off by a stop-cock, at the bottom of the kieve, into an iron boiler sunk in the ground, from whence it is raised into the boiler by a pump. The heat is now elevated to a higher temperature, and the ley again run upon the goods in the kieve; from whence it is returned into the boiler, as before described: and these operations are continued, always increasing the heat, until the alkaline ley is completely saturated with the coloring matter taken from the cloth, which is known by its having acquired a completely offensive smell, and losing its causticity.

When we consider the effect which heated liquids have upon colored vegetable matter, we shall see the propriety of the temperature of the alkaline ley being gradually increased. Thus, when vegetable substances are hastily plunged into boiling liquids, the coloring matter, in place of being extracted, is, by this higher temperature, fixed into them. It is on this principle that a cook acts in the culinary art, when the green color of vegetables is intended to be preserved: in place of putting them into water when cold, they are kept back until the water is boiling; because it is well known that, in the former case, the green color would be entirely extracted, whereas, when the vegetables are not infused until the water is boiling, the color is completely preserved or fixed On the same principle, when the temperature of the alkaline ley is gradually raised, the extractive and coloring matter is more effectually taken from the cloth; and the case is reversed when the ley is applied at the boiling temperature: so much so, that linen which has been so unfortunate as to meet with this treatment, can never be brought to a good white.

When the alkaline ley is saturated with coloring matter, it is run off as unfit for

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further use in this operation; but, were the goods to be instantly taken out of the kieve, and carried to be washed in the dash-wheel while hot, a certain portion of the coloring matter would be again fixed into them, which is extremely difficult to eradicate. In order to prevent this, the most approved bleachers run warm water upon the cloth as soon as the impure ley is run off: this combines with and carries off part of the remaining impurities. A stream of water is then allowed to run upon the cloth in the kieve, until it comes off almost transparent. The goods are now to be taken to the wash stocks, or to the dash-wheel, to be further cleaned, with the greatest efficacy.

The improved mode of bowking was the invention of Mr. John Laurie, a native of Glasgow. It is now practised by many bleachers in Lancashire, some on more perfect plans than others; but we shall give the description of the kind of apparatus approved of by those whose experience and skill have rendered them the most competent judges.

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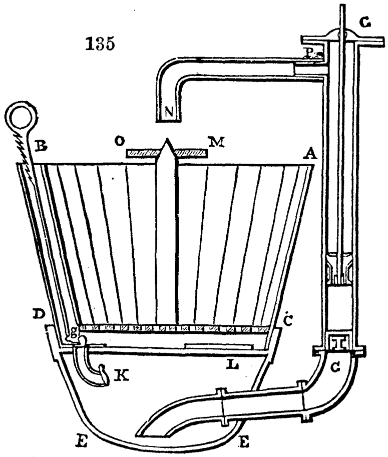

In *fig.* 135, A B C D is the wooden kieve, or kier, containing the cloth; C E F D represents the cast-iron boiler; G G, the pump; *g* K, the pipe of communication between the kieve and the boiler. This pipe has a valve on each of its extremities; that on the upper extremity, when shut, prevents the ley from running into the boiler, and is regulated by the attendant by means of the rod and handle *g* B. The valve at K admits the ley; but, opening inwards, it prevents the steam from escaping through the pipe *g* K. The boiler has a steam-tight iron cover, *g* L; and at C D, in the kieve, is a wooden grating, a small distance above the cover of the boiler.

At M O is a broad plate of metal, in order to spread the ley over the cloth. It is hardly necessary to say that the boiler has a furnace, as usual, for similar purposes.

While the ley is at a low temperature, the pump is worked by the mill or steam-engine. When it is sufficiently heated, the elasticity of the steam forces it up through the valves of the pump, in which case it is disjoined from the moving power.

N P is a copper spout, which is removed at the time of taking the cloth out of the kieve.

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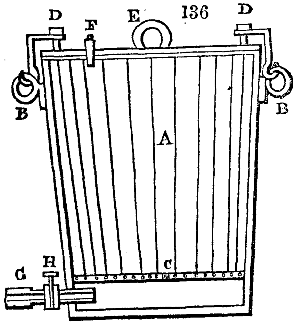
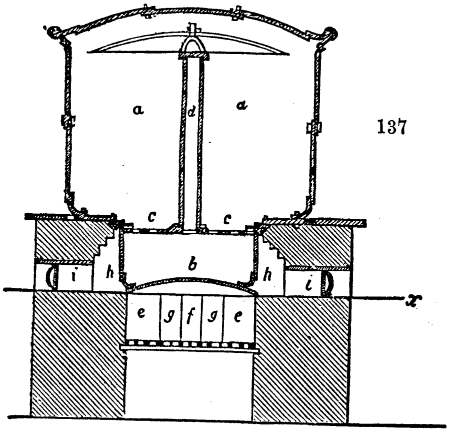


The boilers A, *fig.* 136, used in bleaching, are of the common form, having a stop-cock, H G, at bottom, for running off the waste ley. They are commonly made of cast-iron, and are capable of containing from 300 to 600 gallons of water, according to the extent of the business done. In order that the capacity of the boilers may be enlarged, they are formed so as to admit of a crib of wood, strongly hooped, or, what is preferable, of cast-iron, to be fixed to the upper rim or edge of it. To keep the goods from the bottom, where the heat acts most forcibly, a strong iron ring, covered with netting made of stout rope, c, is allowed to rest six or eight inches above the bottom of the boiler. Four double ropes are attached to the ring E, for withdrawing the goods when sufficiently boiled, which have each an eye for admitting hooks from the running tackle of a crane. Where more boilers than one are employed, the crane is so placed, that, in the range of its sweep, it may withdraw the goods from any of them. For this purpose, the crane turns on pivots at top and bottom; and the goods are raised or lowered at pleasure, with double pulleys and sheaves, by means of a cylinder moved by cast-iron wheels. The lid is secured by the screw bolts D D, and rings B B. F is a safety valve.

The efficacy of Laurie's bowking apparatus is remarkable. While the heat is gradually rising, a current of fresh ley is constantly presented to the different surfaces for saturating the goods, so as to increase its detersive powers. Besides, the manner in which the apparatus is worked, first by the water-wheel or steam-engine, and then by its intrinsic operation, puts it completely out of the power of servants to slight the work; not to speak of the great saving of alkali, which, in many cases, has been found to amount to 25 per cent.



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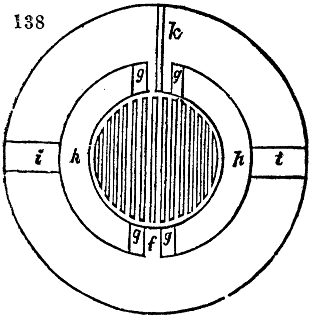
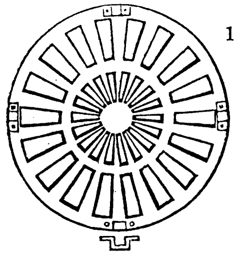


A simple modification of the bowking apparatus is shown in *figs*. 137, 138, 139; the first being a vertical section, the second, a horizontal section in the line *x* of the first. It consists of two parts: the upper wide part, *a a*, serves for the reception of the goods, and the lower or pot, *b*, for holding the ley; *c c* is an iron grating, shown apart in *fig*. 139. The grating has numerous square apertures in the middle of the disc, to which the rising pipe *d* is screwed fast. The upper cylinder is formed of cast iron, or of sheet iron well riveted at the edges; or sometimes of wood, this being secured at its under edge into a groove in the top edge of the ley-pot. The mouth of the cylinder is constructed usually of sheet iron. *e e* is the fire-grate, whose upper surface is shown in *fig*. 138; it is made of cast iron, in three pieces. The flame is parted at *f*, and passes through the two apertures *g g*, into the flues *h h*, so as to play round the pot, as is visible in *fig*. 138; and escapes by two outlets into the chimney. The apertures *i i* serve for occasionally cleaning out the flues *h h*, and are, at other times, shut with an iron plate. In the partition *f*, which separates the two openings *g g*, and the flues *h h*, running round the pot, there is a circular space at the point marked with *k*, *fig*. 138, in which the large pipe for discharging the waste ley is lodged. The upper large cylinder should be incased in wood, with an intermediate space filled with saw-dust, to confine the heat. The action of this apparatus is exactly the same as of that already explained.



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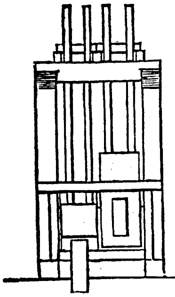
Besides the boiling, bucking, and other apparatus above described, the machinery and utensils used in bleaching are various, according to the business done by the bleacher. When linen or heavy cotton cloths are whitened, and the business is carried on to a considerable extent, the machines are both complicated and expensive. They consist chiefly of a water-wheel, sufficiently powerful for giving motion to the wash-stocks, dash-wheels, squeezers, &c., with any other operations where power is required.

Figs. 140, 141, represent a pair of wash-stocks. A A are called the stocks, or feet. They are suspended on iron pivots at B, and receive their motion from wipers on the revolving shaft C. The cloth is laid in at D, and by the alternate strokes of the feet, and the curved form of the turnhead E, the cloth is washed and gradually turned. At the same time, an abundant stream of water rushes on the cloth throughout holes in the upper part of the turnhead. Wash-stocks are much used in Scotland and in Ireland. In the latter country they are often made with double feet, suspended above and below two turnheads, and wrought with cranks instead of wipers. Wash-stocks, properly constructed, make from 24 to 30 strokes per minute.

This mode of washing is now entirely given up in Lancashire, where a preference is given to what are called dash-wheels and squeezers. The dash are small water-wheels, the inside of which is divided into four compartments, and closed up, leaving only a hole in each compartment for putting in the cloth.

There are, besides, smaller openings for the free admission and egress of the water employed in cleansing. The cloth, by the motion of the wheel, is raised up in one part of the revolution of the wheel; while, by its own weight, it falls in another. This kind of motion is very effectual in washing the cloth, while, at the same time, it does not injure its strength. The plan, however, where economy of water is of any importance, is very objectionable; because the wheel must move at by far too great a velocity to act to advantage as a water-wheel.

141



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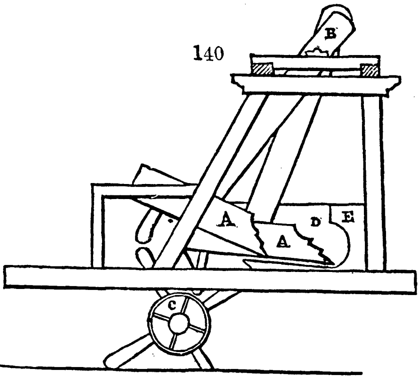

The wash or dash-wheel, now driven by power in all good bleach and print-works, is represented in *fig.* 142, upon the left side in a back view, and upon the right side in a front view (the sketch being halved). *Fig.* 143 is a ground plan.

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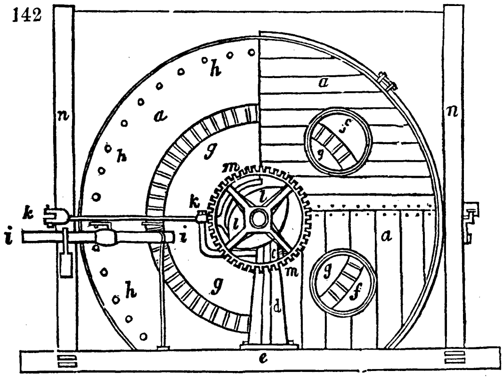
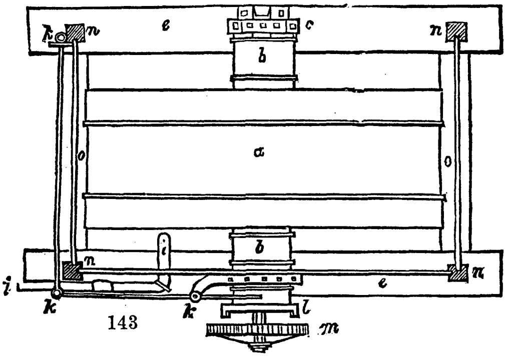


a a is the washing-wheel; *b b* its shaft-ends; *c c* their brass bearings or plummer-blocks, supported upon the iron pillars *d d*. The frame is made of strong beams of wood, *e e*, bound together by cross bars with mortises. *f f*, two of the circular apertures, each leading to a quadrantal compartment within the dash-wheel. In the back view (the left-hand half of the figure) the brass grating *g g*, of a curvilinear form, is seen, through which the jets of water are admitted into the cavity of the wheel; *h h*, are the round orifices, through which the foul water runs off, as each quadrant passes the lower part of its revolution; *i*, a water-pipe, with a stop-cock for regulating the washing-jets; *k k*, the lever for throwing the driving-crab *l*, or coupling-box, into or out of gear with the shaft of the wheel. This machine is so constructed, that the water-cock is opened or shut by the same leverage which throws the wheel into or out of gear. *m*, a wheel, fixed upon the round extremity of the shaft of the dash-wheel, which works into the toothed pinion connected



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with the prime mover. When the end of the lever *k*, whose fork embraces the coupling-box upon the square part of the shaft, is pushed forwards or backwards, it shifts the clutch into or out of gear with the toothed wheel *m*. In the latter case, this wheel turns with its pinion without affecting the dash-wheel. *n n*, holdfasts fixed upon the wooden frame, to which the boards *o o* are attached, for preventing the water from being thrown about by the centrifugal force.

The dash-wheel is generally from 6 to 7 feet in diameter, about 30 inches wide, and requires the power of about two horses to drive it.

From one to two pieces of calico may be done at once in each quadrantal compartment, in the course of 8 or 10 minutes; hence, in a day of 13 hours, with two such wheels 1200 pieces of yard-wide goods may be washed.

After the process of washing by the dash-wheel, the water is expressed from the cloth by means of the squeezers already described.

Bleaching of Linen.—Linen contains much more coloring matter than cotton. The former loses nearly a third of its weight, while the latter loses not more than a twentieth. The fibres of flax possess, in the natural condition, a light gray, yellow, or blond color. By the operation of rotting, or, as it is commonly called, water-retting, which is employed to enable the textile filaments to be separated from the boon, or woody matter, the color becomes darker, and, in consequence probably of the putrefaction of the green matter of the bark, the coloring substance appears. Hence, flax prepared without rotting is much paler, and its coloring matter may be in a great measure removed by washing with soap, leaving the filaments nearly white. Mr. James Lee obtained a patent in 1812, as having discovered that the process of steeping and dew-retting is unnecessary, and that flax and hemp will not only dress, but will produce an equal if not greater quantity of more durable fibre, when cleaned in the dry way. Mr. Lee stated that, when hemp or flax plants are ripe, the farmer has nothing more to do than to pull, spread, and dry them in the sun, and then to break them by proper machinery. This promising improvement has apparently come to naught, having been many years abandoned by the patentee himself, though he was favored with a special act of parliament, which permitted the specification of his patent to remain sealed up for seven years, contrary to the general practice in such cases.

The substance which gives steeped flax its peculiar tint is insoluble in boiling water, in acids, and in alkalis; but it possesses the property of dissolving in caustic or carbonated alkaline leys, when it has possessed the means of dehydrogenation by previous exposure to oxygen. Hemp is, in this respect, analogous to flax. The bleaching of both depends upon this action of oxygen, and upon the removal of the acidified dye, by means of an alkali. This process is effected generally by the influence of air in combination with light and moisture acting on the linen cloth laid upon the grass: but chlorine will effect the same object more expeditiously. In no case, however, is it possible to acidify the color completely at once, but there must be many alternate exposures to oxygen or chlorine, and alkali, before the flax becomes white. It is this circumstance alone which renders the bleaching of linen an apparently complicated business.

Having made these preliminary observations with regard to the method of applying the alkaline leys used in bleaching linen cloth, I shall now bring the whole into one point of view, by detailing the connexion of these processes, as carried on at a bleach-field, which has uniformly been successful in returning the cloth of a good white, and has otherwise given satisfaction to its employers; and I shall only remark, that I by no means hold it up as the best process which may be employed, as every experienced bleacher knows that processes must be varied, not only according to existing circumstances, but also according to the nature of the linens operated upon.

In order to avoid repetition, where washing is mentioned, it must always be understood that the linen is taken to the wash-stocks or dash-wheel, and washed well in them for some hours. This part of the work can never be overdone; and on its being properly executed between every part of the bucking, boiling, steeping in the chloride of lime solution, and souring, not a little of the success of bleaching depends. By exposure is meant, that the linen cloth is taken and spread upon the bleach-green for four, six, or eight days, according as the routine of business calls for the return of the cloth, in order to undergo further operations.

A parcel of goods consists of 360 pieces of those linens which are called Britannias. Each piece is 35 yards long; and they weigh, on an average, 10 lbs. each: the weight of the parcel is, in consequence, about 3600 lbs. avoirdupois weight. The linens are first washed, and then steeped in waste alkaline ley, as formerly described under these processes; they then undergo the following operations:—

1st,	Bucked with	60 lbs.	pearl-ashes,	washed,	exposed on the	field.
2d,	Ditto	80	ditto	ditto	ditto	ditto.
3d,	Ditto	90	potashes	ditto	ditto	ditto.
4th,	Ditto	80	ditto	ditto	ditto	ditto.

5th, Bucked with 80 lbs. pearl-ashes, washed, exposed on the field.
6th, Ditto 50 ditto ditto ditto ditto.
7th, Ditto 70 ditto ditto ditto ditto.
8th, Ditto 70 ditto ditto ditto ditto.
9th, Soured one night in dilute sulphuric acid, washed.
10th, Bucked with 50 lbs. pearl-ashes, washed, exposed on the field.
11th, Immersed in the chloride of potash or lime 12 hours.
12th, Boiled with 30 lbs. pearl-ashes, washed, exposed on the field.
13th, Ditto 30 ditto ditto ditto ditto.
14th, Soured, washed.

The linens are then taken to the rubbing-board, and well rubbed with a strong lather of black soap, after which they are well washed in pure spring water. At this period they are carefully examined, and those which are fully bleached are laid aside to be blued, and made up for the market; while those which are not fully white are returned to be boiled, and steeped in the chloride of lime or potash; then soured, until they are fully white.

By the above process, 690 lbs. weight of alkali is taken to bleach 360 pieces of linen, each piece consisting of 35 yards in length; so that the expenditure of alkali would be somewhat less than 2 lbs. for each piece, were it not that some parts of the linens are not fully whitened, as above noted. Two pounds of alkali may therefore be stated as the average quantity employed for bleaching each piece of goods.

The method of bleaching linens in Ireland is similar to the foregoing; any alteration in the process depending upon the judgment of the bleacher in increasing or diminishing the quantity of alkali used. But it is common, at most bleach-fields, to steep the linens in the chloride of lime or potash at an early stage of the process, or after the goods have undergone the fifth or sixth operation of bucking. By this means those parts of the flax which are most difficult to bleach are more easily acted upon by the alkali; and, as before noticed, souring early in very dilute sulphuric acid, assists greatly in forwarding the whitening of the linens. Mr. Grimshaw, calico-printer, near Belfast, was the first who recommended early souring, which has since been very generally adopted.

The bleaching of Silk.—Silk in its raw state, as spun by the worm, is either white or yellow of various shades, and is covered with a varnish, which gives it stiffness and a degree of elasticity. For the greater number of purposes to which silk is applied, it must be deprived of this native covering, which was long considered to be a sort of gum. The operation by which this coloring matter is removed is called scouring, cleansing, or boiling. A great many different processes have been proposed for freeing the silk fibres from all foreign impurities, and for giving it the utmost whiteness, lustre, and pliancy; but none of the new plans has superseded, with any advantage, the one practised of old, which consists essentially in steeping the silk in a warm solution of soap; a circumstance placed beyond all doubt by the interesting experiments of M. Roard. The alkalis, or alkaline salts, act in a marked manner upon the varnish of silk, and effect its complete solution; the prolonged agency of boiling water, alone answers the same purpose; but nothing agrees so well with the nature of silk, and preserves its brilliancy and suppleness so perfectly, as a rapid boil with soap-water. It would appear, however, that the Chinese do not employ this method, but something that is preferable. Probably the superior beauty of their white silk may be owing to the superiority of the raw material.

The most ancient method of scouring silk consists of three operations. For the first, or the *ungumming*, thirty per cent. of soap is first of all dissolved in clean river water by a boiling heat; then the temperature is lowered by the addition of a little cold water, by withdrawing the fire, or at least by damping it. The hanks of silk, suspended upon horizontal poles over the boiler, are now plunged into the soapy solution, kept at a heat somewhat under ebullition, which is an essential point; for if hotter, the soap would attack the substance of the silk, and not only dissolve a portion of it, but deprive the whole of its lustre. The portions of the hanks plunged in the bath get scoured by degrees; the varnish and the coloring matter come away, and the silk assumes its proper whiteness and pliancy. Whenever this point is attained, the hanks are turned round upon the poles, so that the portion formerly in the air may be also subjected to the bath. As soon as the whole is completely ungummed, they are taken out, wrung by the peg, and shaken out; after which, the next step, called the *boil*, is commenced. Into bags of coarse canvass, called *pockets*, about 25 lbs. or 35 lbs. of ungummed silk are enclosed, and put into a similar bath with the preceding, but with a smaller proportion of soap, which may therefore be raised to the boiling point without any danger of destroying the silk. The ebullition is to be kept up for an hour and a half, during which time the bags must be frequently stirred, lest those near the bottom should suffer an undue degree of heat. The silk experiences in these two operations a loss of about 25 per cent. of its weight.

The third and last scouring operation is intended to give the silk a slight tinge, which

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renders the white more agreeable, and better adapted to its various uses in trade. In this way we distinguish the China white, which has a faint cast of red, the silver white, the azure white, and the thread white. To produce these different shades, we begin by preparing a soap-water so strong as to lather by agitation; we then add to it, for the China white, a little annotto, mixing it carefully in; and then passing the silk properly through it, till it has acquired the wished for tint. As to the other shades, we need only azure them more or less with a fine indigo, which has been previously washed several times in hot water, and reduced to powder in a mortar. It is then diffused through boiling water, allowed to settle for a few minutes, and the supernatant liquid, which contains only the finer particles, is added to the soap bath in such proportion as may be requisite. The silk, on being taken out of this bath, must be wrung well, and stretched upon perches to dry; after which it is introduced into the sulphuring chamber, if it is to be made use of in the white state. At Lyons, however, no soap is employed at the third operation: after the boil, the silk is washed, sulphured, and azured, by passing through very clear river water properly blued.

The silks intended for the manufacture of blonds and gauzes are not subjected to the ordinary scouring process, because it is essential, in these cases, for them to preserve their natural stiffness. We must therefore select the raw silk of China, or the whitest raw silks of other countries; steep them, rinse them in a bath of pure water, or in one containing a little soap; wring them, expose them to the vapor of sulphur, and then pass them through the azure water. Sometimes this process is repeated.

Before the memoir of M. Roard appeared, extremely vague ideas were entertained about the composition of the native varnish of silk. He has shown that this substance, so far from being of a gummy nature, as had been believed, may be rather compared to bees' wax, with a species of oil, and a coloring matter, which exists only in raw silks. It is contained in them to the amount of from 23 to 24 per cent., and forms the portion of weight which is lost in the *ungumming*. It possesses, however, some of the properties of vegetable gums, though it differs essentially as to others. In a dry mass, it is friable and has a vitreous fracture; it is soluble in water, and affords a solution which lathers like soap; but when thrown upon burning coals, it does not soften like gum, but burns with the exhalation of a fetid odor. Its solution, when left exposed to the open air, at first of a golden yellow, becomes soon greenish, and ere long putrefies, as a solution of animal matter would do in similar circumstances. M. Roard assures us that the city of Lyons alone could furnish several thousand quintals of this substance *per annum*, were it applicable to any useful purpose.

The yellow varnish is of a resinous nature, altogether insoluble in water, very soluble in alcohol, and contains a little volatile oil, which gives it a rank smell. The color of this resin is easily dissipated, either by exposure to the sun or by the action of chlorine: it forms about one fifty-fifth of its weight.

Bees' wax exists also in all the sorts of silk, even in that of China; but the whiter the filaments, the less wax do they contain.

M. Roard has observed that, if the silk be exposed to the soap baths for some time after it has been stripped of its foreign matters, it begins to lose body, and has its valuable qualities impaired. It becomes dull, stiff, and colored in consequence of the solution more or less considerable of its substance; a solution which takes place in all liquids, and even in boiling water. It is for this reason that silks cannot be alumed with heat; and that they lose some of their lustre in being dyed brown, a color which requires a boiling hot bath. The best mode, therefore, of avoiding these inconveniences, is to boil the silks in the soap-bath no longer than is absolutely necessary for the scouring process, and to expose them in the various dyeing operations to as moderate temperature as may be requisite to communicate the color. When silks are to be dyed, much less soap should be used in the cleansing, and very little for the dark colors. According to M. Roard, raw silks, white or yellow, may be completely scoured in one hour, with 15 lbs. of water for one of silk, and a suitable proportion of soap. The soap and the silk should be put into the bath half an hour before its ebullition, and the latter should be turned about frequently. The dull silks, in which the varnish has already undergone some alteration, never acquire a fine white until they are exposed to sulphureous acid gas. Exposure to light has also a very good effect in whitening silks, and is had recourse to, it is said, with advantage by the Chinese.

Carbonate of soda has been proposed to be used instead of soap in scouring silk, but it has never come into use. The Abbé Collomb, in 1785, scoured silk by eight hours' boiling in simple water, and he found the silks bleached in this way to be stronger than by soap, but they are not nearly so white. A patent has been taken out in England for bleaching them by steam, of which an account will be found under the article Silk.

It appears that the Chinese do not use soap in producing those fine white silks which are imported into Europe. Michel de Grubbens, who resided long at Canton, saw and practised himself the operation there, which he published in the Memoirs of the Academy of Stockholm in 1803. It consists in preparing the silk with a species of white beans, smaller than the Turkey beans, with some wheat flour, common salt, and water. The proportions are 5 parts of beans, 5 of salt, 6 of flour, and 25 of water, to form this vegetable bath. The beans must be previously washed. It is difficult to discover what chemical action can occur between that decoction and the varnish of raw silk; possibly some acid may be developed, which may soften the gummy matter, and facilitate its separation.

Baumé contrived a process which does not appear to have received the sanction of experience, but which may put us in the right way. He macerates the yellow raw silk in a mixture of alcohol at 36° (sp. gr. 0837) and one thirty-second part of pure muriatic acid. At the end of forty-eight hours, it is as white as possible, and the more so, the better the quality of the silk. The loss which it suffers in this menstruum is only one fortieth; showing that nothing but the coloring matter is abstracted. The expense of this menstruum is the great obstacle to Baumé's process. The alcohol, however, might be in a very great measure recovered, by saturating the acid with chalk, and redistillation.

Bleaching of Wool.—Wool, like the preceding fibrous matter, is covered with a peculiar varnish, which impairs its qualities, and prevents it from being employed in the raw state for the purposes to which it is well adapted when it is scoured. The English give the name *yolk*, and the French *suint*, to that native coat: it is a fatty unctuous matter, of a strong smell, which apparently has its chief origin in the cutaneous perspiration of the sheep; but which, by the agency of external bodies, may have undergone some changes which modify its constitution. It results from the experiments of M. Vauquelin, that the *yolk* is composed of several substances; namely, 1, a soap with basis of potash, which constitutes the greater part of it; 2, of a notable quantity of acetate of potash; 3, of a small quantity of carbonate, and a trace of muriate, of potash; 4, of a little lime in an unknown state of combination; 5, of a species of sebaceous matter, and an animal substance to which the odor is due. There are several other accidental matters present on sheeps' wool.

The proportion of yolk is variable in different kinds of wool, but in general it is more abundant the finer the staple; the loss by scouring being 45 per cent. for the finest wools, and 35 per cent. for the coarse.

The yolk, on account of its soapy nature, dissolves readily in water, with the exception of a little free fatty matter, which easily separates from the filaments, and remains floating in the liquor. It would thence appear sufficient to expose the wools to simple washing in a stream of water; yet experience shows that this method never answers so well as that usually adopted, which consists in steeping the wool for some time in simple warm water, or in warm water mixed with a fourth of stale urine. From 15 to 20 minutes of contact are sufficient in this case, if we heat the bath as warm as the hand can bear it, and stir it well with a rod. At the end of this time the wool may be taken out, set to drain, then placed in large baskets, in order to be completely rinsed in a stream of water.

It is generally supposed that putrid urine acts on the wool by the ammonia which it contains, and that this serves to saponify the remainder of the fatty matter not combined with the potash. M. Vauquelin is not of this opinion, because he found that wool steeped in water, with sal ammoniac and quick lime, is not better scoured than an equal quantity of wool treated with mere water. He was hence led to conclude that the good effects of putrefied urine might be ascribed to anything else besides the ammonia, and probably to the urea. Fresh urine contains a free acid, which, by decomposing the potash soap of the yolk, counteracts the scouring operation.

If wools are better scoured in a small quantity of water than in a great stream, we can conceive that this circumstance must depend upon the nature of the yolk, which, in a concentrated solution, acts like a saponaceous compound, and thus contributes to remove the free fatty particles which adhere to the filaments. It should also be observed that too long a continuance of the wool in the yolk water, hurts its quality very much, by weakening its cohesion, causing the filaments to swell, and even to split. It is said then to have lost its *nerve*. Another circumstance in the scouring of wool, that should always be attended to, is never to work the filaments together to such a degree as to occasion their felting; but in agitating we must merely push them slowly round in the vessel, or press them gently under the feet. Were it at all felted, it would neither card nor spin well

As the heat of boiling water is apt to decompose woollen fibres, we should be careful never to raise the temperature of the scouring bath to near this point, nor, in fact, to exceed 140° F. Some authors recommend the use of alkaline or soapy baths for scouring wool, but practical people do not deviate from the method above described.

When the washing is completed, all the wool which is to be sent white into the market, must be exposed to the action of sulphurous acid, either in a liquid or a gaseous state. In the latter case, sulphur is burned in a close chamber, in which the wools are hung up or spread out; in the former, the wools are plunged into water, moderately impregnated with the acid. (See Sulphuring.) Exposure on the grass may also contribute to the bleaching of wool. Some fraudulent dealers are accused of dipping wools in butter-milk, or chalk and water, in order to whiten them and increase their weight.

Wool is sometimes whitened in the fleece, and sometimes in the state of yarn; the latter affording the best means of operating. It has been observed that the wool cut from certain parts of the sheep, especially from the groins, never bleaches well.

After sulphuring, the wool has a harsh crispy feel, which may be removed by a weak soap bath. To this also the wool comber has recourse when he wishes to cleanse and whiten his wools to the utmost. He generally uses a soft or potash soap, and after the wool is well soaked in the warm soap bath, with gentle pressure he wrings it well with the help of a hook, fixed at the end of his washing tub, and hangs it up to dry.

Bleaching of rags, and paste for paper making.—After the rags are reduced to what is called half stuff, they should have the greater part of the floating water run off, leaving just enough to form a stir-about mass. Into this a clear solution of chloride of lime should be poured, of such a strength as is suited to the color of the rags, which should have been previously sorted; and the engine is kept going so as to churn the rags with the bleaching agent. After an hour, the water may be returned upon the engine, and the washing of the paper resumed. From two to four pounds of good chloride of lime are reckoned sufficient to bleach one hundred weight of rags.

When the rags consist of dyed or printed cottons, after being well washed and reduced to half stuff, they should be put into a large cask or butt, supported horizontally by iron axles upon cradle bearings, so that it may be made to revolve like a barrel-churn. For each hundred weight of the colored rags, take a solution containing from four to eight pounds of chloride of lime; add it to the liquid mixture in the butt along with half a pound of sulphuric acid for every pound of the chloride; and after inserting the bung, or rather the square valve, set the vessel in slow revolution backwards and forwards. In a short time the rags will be colorless. The rags and paper paste ought to be very well washed, to expel all the chlorine, and perhaps a little muriatic acid might be used with advantage to dissolve out all the calcareous matter, a portion of which is apt to remain in the paper, and to operate injuriously upon both the pens and the ink. Some of the French paper manufacturers bleach the paste with chlorine gas. Paper prepared from such paste, well washed, is not apt to give a brown tint to maps, as that carelessly bleached with chloride of lime is known to do.

BLEACHING OF PAPER. The following are the proportions of liquid chloride of lime, at 10° of Gay Lussac's *Chlorometre*, employed for the different sorts of rags, consisting of two piles, or 200 pounds French.

Cotton.		litres.
No. 1.	Fine cotton rags	10
2.	Clean calicoes	12
3.	———	14
4.	White dirty calico, coarse cotton	16
5.	Coarse cotton	18
6.	Grey, No. 1	20
	—— No. 2	22
	Saxon gray	24
	——— No. 2	26
	Pale white and half-white shades	28
	Saxon blues; pale pink, dark blue, velvet	32

It is considered to be much better to bleach the fine rags with liquid chloride of lime, and not with chlorine gas, because they are less injured by the former, and afford a paper of more nerve, less apt to break, and more easily sized. But the coarse or gray rags are much more economically bleached with the gaseous chlorine, without any risk of weakening the fibre too much. Bleaching by the gas is performed always upon the sorted rags, which have been boiled in an alkaline ley, and torn into the fibrous state. They are subjected to the press, in order to form them into damp cakes, which are broken in pieces and placed in large rectangular wooden cisterns. The chlorine gas is introduced by tubes in the lid of the cistern, which falls down by its superior gravity, acting always more strongly upon the rags at the bottom than those above.

When the chlorine, disengaged from 150 kilogrammes (330 lbs.) of manganese and 500 kilos. of muriatic acid, is made to act upon 2,500 kilos. of the stuff (supposed dry), it will have completed its effect in the course of a few hours. The quantity of gaseous chlorine is equal to what is contained in the quantity of chloride of lime requisite to produce a like bleaching result. The bleached stuff should be forthwith carefully washed to remove all the muriatic acid produced from the chlorine; for if any of this remain in the paper, it destroys lithographic stones and weakens common ink.

BLENDE. (Fr. and Germ.) Sulphuret of zinc, so named from the German *blenden*, to dazzle, on account of its glistening aspect. It is called black jack from its usual color. Its lustre is pearly adamantine. Spec. gravity from 3·7 to 4·2. It contains frequently iron, copper, arsenic, cadmium and silver, all associated with sulphur. It is worked up partly into metallic zinc, and partly into the sulphate of zinc, or white vitriol. It consists of 66·72 zinc, and 33·28 sulphur; being nearly by weight as two to one. See ZINC.

BLOCK MANUFACTURE. Though the making of ships' blocks belongs rather to a dictionary of engineering than of manufactures, it may be expected that I should give some account of the automatic machinery for making blocks, so admirably devised and mounted by M. I. Brunel Esq., for the British navy, in the dockyard of Portsmouth.

The series of machines and operations are as follows:—

1. *The straight cross cutting saw.*—The log is placed horizontally on a very low bench, which is continued through the window of the mill into the yard. The saw is exactly over the place where the log is to be divided. It is let down, and suffered to rest with its teeth upon the log, the back still being in the cleft of the guide. The crank being set in motion, the saw reciprocates backwards and forwards with exactly the same motion as if worked by a carpenter, and quickly cuts through the tree. When it first begins to cut, its back is in the cleft in the guide, and this causes it to move in a straight line; but before it gets out of the guide, it is so deep in the wood as to guide itself; for in cutting across the grain of the wood, it has no tendency to be diverted from its true line by the irregular grain. When the saw has descended through the tree, its handle is caught in a fixed stop, to prevent its cutting the bench. The machine is thrown out of gear, the attendant lifts up the saw by a rope, removes the block cut off, and advances the tree to receive a fresh cut.

2. *The circular cross cutting saw.*—This saw possesses universal motion; but the axis is always parallel to itself, and the saw in the same plane. It can be readily raised or lowered, by inclining the upper frame on its axis; and to move it sidewise, the saw frame must swing sidewise on its joints, which connect it with the upper frame. These movements are effected by two winches, each furnished with a pair of equal pinions, working a pair of racks fixed upon two long poles. The spindles of these winches are fixed in two vertical posts, which support the axis of the upper frame. One of these pairs of poles is jointed to the extreme end of the upper frame; therefore by turning the handle belonging to them, the frame and saw is elevated or depressed; in like manner, the other pair is attached to the lower part of the saw frame, so that the saw can be moved sidewise by means of their handles, which then swing the saw from its vertical position.

These two handles give the attendant a complete command of the saw, which we suppose to be in rapid motion, the tree being brought forward and properly fixed. By one handle, he draws the saw against one side of the tree, which is thus cut into (perhaps half through); now, by the other handle, he raises the saw up, and by the first-mentioned handle he draws it across the top of the tree, and cuts it half through from the upper side; he then depresses the saw and cuts half through from the next side; and lastly a trifling cut of the saw, at the lower side, completely divides the tree, which is then advanced to take another cut.

The great reciprocating saw is on the same principle as the saw mill in common use in America.

3. *The circular ripping saw* is a thin circular plate of steel, with teeth similar to those of a pit saw, formed in its periphery. It is fixed to a spindle placed horizontally, at a small distance beneath the surface of a bench or table, so that the saw projects through a crevice a few inches above the bench. The spindle being supported in proper collars, has a rapid rotatory motion communicated to it by a pulley on the opposite end, round which an endless strap is passed from a drum placed overhead in the mill. The block cut by the preceding machine from the end of the tree, is placed with one of the sides flat upon the bench, and thus slides forward against the revolving saw which cuts the wood with a rapidity incredible to any one who has not seen these or similar machines.

4. *Boring machine.*—The blocks, prepared by the foregoing saws, are placed in the machine represented in *fig.* 144. This machine has an iron frame, A A, with three legs, beneath which the block is introduced, and the screw near B being forced down upon it, confines it precisely in the proper spot to receive the borers D and E. This spot is determined by a piece of metal fixed perpendicularly just beneath the point of the borer E, shown separately on the ground at X; this piece of metal adjusts the position for the borer D, and its height is regulated by resting on the head of the screw X, which fastens the piece X down to the frame. The sides of the block are kept in a parallel position, by being applied against the heads of three screws tapped into the double leg of the frame A. The borer D is adapted to bore the hole for the centre pin in a direction exactly per-

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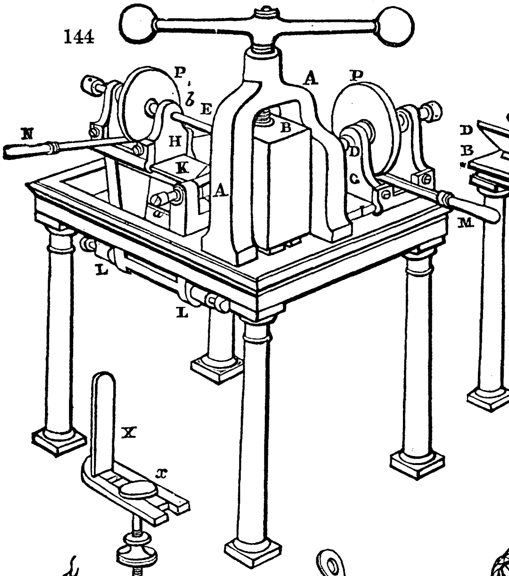

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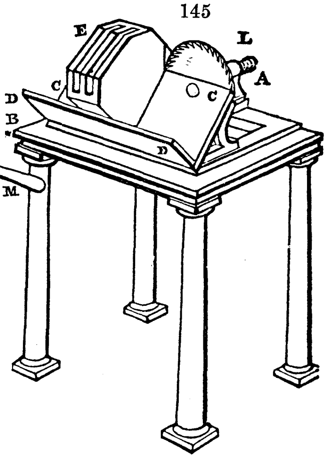
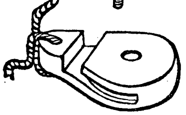
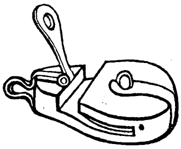
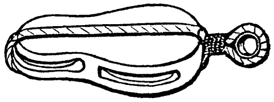






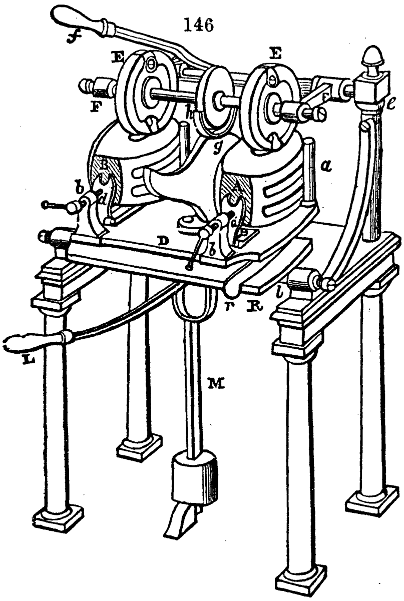


pendicular to the surface resting against the three screws; the other, at E, perforates the holes for the commencement of the sheave holes. Both borers are constructed in nearly the same manner; they are screwed upon the ends of small mandrels, mounted in frames similar to a lathe. These frames, G and H, are fitted with sliders upon the angular edges of the flat broad bars, I and K. The former of these is screwed fast to the frame; the latter is fixed upon a frame of its own, moving on the centre screws, at L L, beneath the principal frame of the machine. By this means the borer E can be moved within certain limits, so as to bore holes in different positions. These limits are determined by two screws, one of which is seen at *a*; the other, being on the opposite side, is invisible. They are tapped through fixed pieces projecting up from the frame. A projecting piece of metal, from the under side of the slider K of the borer E, stops against the ends of these screws, to limit the excursion of the borer. The frames for both borers are brought up towards the block by means of levers M and N. These are centred on a pin, at the opposite sides of the frame of the machine, and have oblong grooves through them, which receive screw pins, fixed into the frames G and H, beneath the pulleys P P, which give motion to the spindles.

5. *The mortising machine* is a beautiful piece of mechanism, but too complicated for description within the limits prescribed to this article.

6. *The corner saw, fig.* 145, consists of a mandrel, mounted in a frame A, and carrying a circular saw L upon the extreme end of it. This mandrel and its frame being exactly similar to those at G and H, *fig.* 144, does not require a separate view, although it is hid behind the saw, except the end of the screw, marked A. This frame is screwed down upon the frame B B of the machine, which is supported upon four columns. C C, D D, is an inclined bench, or a kind of trough, in which a block is laid, as at E, being supported on its edge by the plane C C of this bench, and its end kept up to its position by the other part of the bench D D.

By sliding the block along this bench, it is applied to the saw, which cuts off its angles, as is evident from the figure, and prepares it for the shaping engine. All the four angles are cut off in succession, by applying its different sides to the trough, or bench. In the figure, two of them are drawn as being cut, and the third is just marked by the saw. This machine is readily adapted to different sizes of blocks, by the simple expedient of laying pieces of wood of different thickness against the plane D D, so as to fill it up, and keep the block nearer to or farther from the saw; for all the blocks are required to be cut at the same angle, though, of course, a larger piece is to be cut from large than from small blocks. The block reduced to the state of E is now taken to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7. *The shaping machine.*—A great deal of the apparent complication of this figure arises from the iron cage, which is provided to defend the workmen, lest the blocks, which are revolving in the circles, or chuck, with an immense velocity, should be loosened by the action of the tool, and fly out by their centrifugal force. Without this provision, the consequences of such an accident would be dreadful, as the blocks would be projected in all directions, with an inconceivable force.

8. *The scoring engine* receives two blocks, as they come from the shaping engine, and forms the groove round their longest diameters for the reception of their ropes or straps, as represented in the two snatch blocks and double block, under *figs.* 144, 145.

A, B, *fig.* 146, represent the above two blocks, each held between two small pillars *a* (the other pillar is hid behind the block), fixed in a strong plate D, and pressed against the pillars by a screw *b*, which acts on a clamp *d*. Over the blocks a pair of circular planes or cutters, E E, are situated, both being fixed on the same spindle, which is turned by a pulley in the middle of it. The spindle is fitted in a frame F F, moving in centres at *e e*, so as to rise and fall when moved by a handle *f*. This brings the cutters down upon the blocks; and the depth to which they can cut is regulated by a curved shape *g*, fixed by screws upon the plate D, between the blocks. Upon this rests a curved piece of metal *h*, fixed to the frame F, and enclosing, but not touching, the pulley. To admit the cutters to traverse the whole length of the blocks, the plate D (or rather a frame beneath it) is sustained between the points of two centres. Screws are seen at *l*, on these centres. The frame inclines when the handle L is depressed. At M is a lever, with a weight at the end of it, counterbalancing the weight of the blocks, and plate D, all which are above the centre on which they move. The frame F is also provided with a counterpoise to balance the cutters, &c. The cutters E E are circular wheels of brass, with round edges. Each has two notches in its circumference, at opposite sides; and in these notches chisels are fixed by screws, to project beyond the rim of the wheel, in the manner of a plane iron before its face.

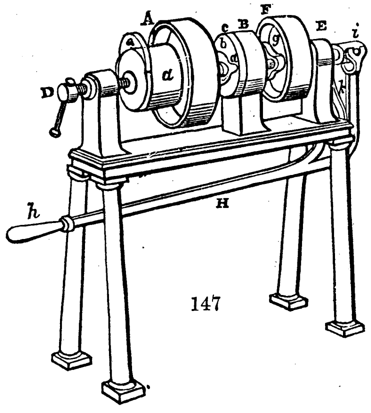
This machine is used as follows:—In order to fix the block, it is pressed between the two pins (only one of which at *a*, can be seen in this view), and the clamp *d*, screwed up against it, so as just to hold the block, but no more. The clamp has two claws, as is seen in the figure, each furnished with a ring entering the double prints previously made, in the end of the block. These rings are partly cut away, leaving only such a segment of each as will just retain the block, and the metal between them is taken out to admit the cutter to operate between them, or nearly so. In putting the blocks into this machine, the workman applies the double prints to the ends of the claws of the clamps, but takes care that the blocks are higher between the pins *a* than they should be: he then takes the handle *f*, and by it presses the cutters E E (which we suppose are standing still) down upon the blocks, depressing them between their pins at the same time, till the descent of the cutters is stopped by the piece *h* resting on the shape *g*. He now turns the screws *b b*, to fix the blocks tight. The cutters being put in motion cut the scores, which will be plainly seen by the mode of adjustment just described, to be of no depth at the pin-hole; but by depressing the handle L, so as to incline the blocks, and keeping the cutters down upon their shape *g*, by the handle *f*, they will cut any depth towards the ends of the blocks, which the shape *g* admits.

By this means one quarter of the score is formed; the other is done by turning both blocks together half round in this manner. The centres *l* are not fitted into the plate D itself, but into a frame seen at R beneath the plate, which is connected with it by a centre pin, exactly midway between the two blocks A B. A spring catch, the end of which is seen at *r*, confines them together; when this catch is pressed back, the plate D can be turned about upon its centre pin, so as to change the blocks, end for end, and bring the unscored quarters (*i. e.* over the clamps) beneath the cutters; the workman taking the handles *f* and L, one in each hand, and pressing them down, cuts out the second quarter. This might have been effected by simply lifting up the handle L; but in that case the cutter would have struck against the grain of the wood, so as to cut rather roughly; but by this ingenious device of reversing the blocks, it always cuts clean and smooth, in the direction of the grain. The third and fourth quarters of the score are cut by turning the other sides of the blocks upwards, and repeating the above operation. The shape *g* can be removed, and another put in its place, for different sizes and curves of block; but the same pins *a*, and holding clamps *d*, will suit many different sizes.

By these machines the shells of the blocks are completely formed, and they are next polished and finished by hand labor; but as this is performed by tools and methods which are well known, it is needless to enter into any explanation: the finishing required being only a smoothing of the surfaces. The machines cut so perfectly true as to require no wood to be removed in the finishing; but as they cut without regard to the irregularity of the grain, knots, &c., it happens that many parts are not so smooth as might be wished, and for this purpose manual labor alone can be employed.

The lignum vitæ for the sheaves of the blocks, is cut across the grain of the wood by two cross-cutting saws, a circular and straight saw, as before mentioned. These machines do not essentially differ in their principle from the great cross-cutting saws we have described, except that the wood revolves while it is cutting, so that a small saw will reach the centre of a large tree, and at the same time cut it truly flat. The limits prescribed for our plates will not admit of giving drawings of these machines, and the idea which could be derived from a verbal description would not be materially different from the cross-cutting saws before mentioned. These machines cut off their plates for the end of the tree, which are exactly the thickness for the intended sheave. These pieces are of an irregular figure, and must be rounded and centred in the crown saw.

9. *The crown saw* is represented in *fig.* 147, where A is a pulley revolving by means of an endless strap. It has the crown or trepan saw *a* fixed to it, by a screw cut within the piece, upon which the saw is fixed, and which gives the ring or hoop of the saw sufficient stability to perform its office. Both the pulleys and saw revolve together upon a truly cylindrical tube *b*, which is stationary, being attached by a flaunch *c* to a fixed puppet B, and on this tube as an axis the saw and pulley turn, and may be slid endwise by a collar fitted round the centre-piece of the pulley, and having two iron rods (only one of which can be seen at *d* in the figure), passing through holes made through the flaunch and puppet B. When the saw is drawn back upon its central tube, the end of the latter projects beyond the teeth of the saw. It is by means of this fixed ring or tube within the saw, that the piece of wood *e* is supported during the operation of sawing, being pressed forcibly against it by a screw D, acting through a puppet fixed to the frame of the machine. At the end of this screw is a cup or basin which applies itself to the piece of wood, so as to form a kind of vice, one side being the end of the fixed tube, the other the cup at the end of the screw D. Within the tube *b* is a collar for supporting a central axis, which is perfectly cylindrical. The other end of this axis, (seen at *f*,) turns in a collar of the fixed puppet E. The central axis has a pulley F, fixed on it, and giving it motion by a strap similar to the other. Close to the latter pulley a collar *g* is fitted on the centre piece of the pulley, so as to slip round freely, but at the same time confined to move endways with the pulley and its collar. This collar receives the ends of the two iron rods *d*. The opposite ends of these rods are, as above mentioned, connected by a similar collar, with the pulley A of the saw *a*. By this connexion, both the centre bit, which is screwed into the end of the central axis *f*, and the saw sliding upon the fixed tube *b*, are brought forward to the wood at the same time, both being in rapid motion by their respective pulleys.



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10. *The Coaking Engine.*—This ingenious piece of machinery is used to cut the three

semicircular holes which surround the hole bored by the crown saw, so as to produce a cavity in the centre of the disc.

11. *Face-turning Lathe.*—The sheave is fixed against a flat chuck at the end of a mandrel, by a universal chuck, similar to that in the coaking engine, except that the centre pin, instead of having a nut, is tapped into the flat chuck, and turned by a screw-driver.

BLOOD. (*Sang*, Fr.; *Blut*, Germ.) The liquid which circulates in the arteries and veins of animals; bright red in the former and purple in the latter, among all the tribes whose temperature is considerably higher than that of the atmosphere. It consists, 1. of a colorless transparent solution of several substances in water; and, 2. of red, undissolved particles diffused through that solution. Its specific gravity varies with the nature and health of the animal; being from 1·0527 to 1·0570 at 60° F. It has a saline sub-nauseous taste, and a smell peculiar to each animal. When fresh drawn from the vessels, it rapidly coagulates into a gelatinous mass, called the clot, cruor, or crassamentum, from which, after some time, a pale yellow fluid, passing into yellowish green, oozes forth, called the *serum*. If the warm blood be stirred with a bundle of twigs, as it flows from the veins, the fibrine concretes, and forms long fibres and knots, while it retains its usual appearance in other respects. The clot contains fibrine and coloring matter in various proportions. Berzelius found in 100 parts of the dried clot of blood, 35 parts of fibrine; 58 of coloring matter; 1·3 of carbonate of soda; 4 of an animal matter soluble in water, along with some salts and fat. The specific gravity of the serum varies from 1·027 to 1·029. It forms about three fourths of the weight of the blood, has an alkaline reaction, coagulates at 167° F. into a gelatinous mass, and has for its leading constituent *albumen* to the amount of 8 per cent., besides fat, potash, soda, and salts of these bases. Blood does not seem to contain any gelatine.

The red coloring matter called *hematine*, may be obtained from the cruor by washing with cold water and filtering.

Blood was at one time largely employed for clarifying sirup, but it is very sparingly used by the sugar refiners in Great Britain of the present day. It may be dried by evaporation at a heat of 130° or 140°, and in this state has been transported to the colonies for purifying cane juice. It is an ingredient in certain adhesive cements, coarse pigments for protecting walls from the weather, for making animal charcoal in the Prussian blue works, and by an after process, a decoloring carbon. It is used in some Turkey red dye-works. Blood is a powerful manure.

BLOWING MACHINE. See IRON, METALLURGY, VENTILATION.

BLOWPIPE. (*Chalumeau*, Fr.; *Lothröhre*, Germ.) Jewellers, mineralogists, chemists, enamellers, &c., make frequent use of a tube, usually bent near the end, terminated with a finely pointed nozzle, for blowing through the flame of a lamp, candle, or gas-jet, and producing thereby a small conical flame possessing a very intense heat. Modifications of blow pipes are made with jets of hydrogen, oxygen, or the two gases mixed in due proportions.

BLUE DYES. (*Teint*, Germ. See ENAMEL.) The materials employed for this purpose are indigo, Prussian blue, logwood, bilberry, (*vaccinium myrtillus*,) elder berries, (*sambucus nigra*,) mulberries, privet berries, (*ligustrum vulgare*,) and some other berries whose juice becomes blue by the addition of a small portion of alkali, or of the salts of copper. For dyeing with the first three articles, see them in their alphabetical places. I shall here describe the other or minor blue dyes.

To dye blue with such berries as the above, we boil one pound of them in water, adding one ounce of alum, of copperas, and of blue vitriol, to the decoction, or in their stead equal parts of verdigris and tartar, and pass the stuffs a sufficient time through the liquor. When an iron mordant alone is employed, a steel blue tint is obtained; and when a tin one, a blue with a violet cast. The privet berries which have been employed as sap colors by the card painters, may be extensively used in the dyeing of silk. The berries of the African night-shade (*solanum guineense*) have been of late years considerably applied to silk on the continent in producing various shades of blue, violet, red, brown, &c., but particularly violet. With alkalis and acids these berries have the same habitudes as bilberries; the former turning them green, the latter red. They usually come from Italy compressed in a dry cake, and are infused in hot water. The infusion is merely filtered, and then employed without any mordant, for dyeing silk, being kept at a warm temperature by surrounding the bath vessel with hot water. The goods must be winced for six hours through it in order to be saturated with color; then they are to be rinsed in running water and dried. One pound of silk requires a pound and a half of the berry, cake. In the residuary bath, other tints of blue may be given. Sometimes the dyed silk is finished by running it through a weak alum water. A color approaching to indigo in permanence, but which differs from it in being soluble in alkalis, though incapable of similar disoxydizement, is the *gardenia genipa* and *aculeata* of South America, whose colorless juice becomes dark blue with contact of air; and dyes stuffs, the skin, and nails of an unchangeable deep blue color, but the juice must be applied in the colorless state. See Indigo and Prussian Blue.

BLUE PIGMENTS. Several metallic compounds possess a blue color; especially those of iron, cobalt, and molybdenum. The metallic pigments, little if at all employed, but which may be found useful in particular cases, are the molybdate of mercury, the hydro-sulphuret of tungsten, the prussiate of tungsten, the molybdate of tin, the oxide of copper darkened with ammonia, the silicate of copper, and a fine violet color formed from manganese and molybdenum. The blues of vegetable origin, in common use, are indigo, litmus, and blue cakes. The blue pigments of a metallic nature found in commerce are the following; *Prussian blue ; mountain blue*, a carbonate of copper mixed with more or less earthy matter; *Bremen blue* or *verditer*, a greenish blue color obtained from copper mixed with chalk or lime; *iron blue*, phosphate of iron, little employed; *cobalt blue*, a color obtained by calcining a salt of cobalt with alumina or oxide of tin; *smalt*, a glass colored with cobalt and ground to a fine powder; *charcoal blue*, a deep shade obtained by triturating carbonized vine stalks with an equal weight of potash in a crucible till the mixture ceases to swell, then pouring it upon a slab, putting it into water, and saturating the alkali with sulphuric acid. The liquor becomes blue, and lets fall a dark blue precipitate, which becomes of a brilliant blue color when heated.

Molybdenum blue is a combination of this metal, and oxide of tin, or phosphate of lime. It is employed both as a paint, and an enamel color. A blue may also be obtained by putting into molybdic acid (made by digesting sulphuret of molybdenum with nitric acid) some filings of tin and a little muriatic acid. The tin deoxidizes the molybdic acid to a certain degree, and converts it into the molybdous, which, when evaporated and heated with alumina recently precipitated, forms this blue pigment. *Ultramarine* is a beautiful blue pigment, which see.

BLUE. Turnbull's and Chinese are both double cyanides of iron.

BLUE VITRIOL; sulphate of copper.

BOILERS (*construction of*).—The modifications of the steam engine which have been adopted since its introduction by Watt, three quarters of a century ago, have been very numerous and varied; and although the progression in its applications and improvements has been most rapid and wonderful, we are still undecided as to the best form of its construction. Sound principles scientifically applied, and the gradually increasing excellence of our mechanical workshops, have enabled us to attain the great perfection which characterizes the working parts of the modern steam engine. The steam engine itself may be regarded as a comparatively perfect machine, and therefore we shall confine our observations almost exclusively to that very important and necessary adjunct—the *Boiler*—which is the source of its power. With this limitation, a very wide field of inquiry is opened out, and in the earliest steps of the investigation we become perplexed with the endless variety of forms and constructions which at different periods have been adopted by engineers, and which have never, unfortunately, received the same judicious attention that was paid, as I have already remarked, to the steam engine. This is an anomalous and much to be regretted fact, for the boiler, being the source of the motive power, is undoubtedly one of the most important parts of the whole machine. Upon its proper proportions and arrangements for the generation of steam, depend the economy and regularity with which the engine can be worked, and upon its strength and excellence of workmanship depends the safety of the lives and property of those who come in contact with it. Regarding the steam engine as one of the most active agents in the extension of our prosperity, and in the civilization of the world, and seeing how it is mixed up with the daily duties and working of society, the safety and efficiency of every part, and more especially the boiler, are subjects of national importance; and it is of great consequence to introduce here such knowledge and experience on this subject of deep interest as has been offered by William Fairbairn, Esq.

"The boiler may be considered in its construction, management, security, and economy. 1st. As to the construction. Here I shall have to go a little into detail, in order to show, in construction, the absolute necessity there exists for adhering to form and other considerations essential in the practice of mechanical engineers, so as to effect the maximum of strength, with the minimum of material. In boilers this is the more important, as any increase in the thickness of the plates obstructs the transmission of heat, and exposes the rivets as well as the plates to injury on the side exposed to the action of the furnace.

"It has generally been supposed that the rolling of boiler plate iron gives to the sheets greater tenacity in the direction of their length than in that of their breadth; this is, however, not correct; as a series of experiments which Mr. Fairbairn made some years since fully proves that there is no difference in the tensile strength of boiler plates whether torn asunder in the direction of the fibre, or across it. From five different sorts of iron the following results were obtained :—

Description of Iron.	Mean Breaking weight in tons, in the direction of the fibre.	Mean Breaking weight in tons across the fibre.
Yorkshire plates	25·77	27·49
Yorkshire plates	22·76	26·37
Derbyshire plates	21·68	18·65
Shropshire plates	22·82	22·00
Staffordshire plates	19·56	21·01
Mean	22·51	23·10

"From this it appears that we may safely use iron plates in the construction of boilers, in whatever direction may best suit the convenience of the maker. Next to the tenacity of the plates comes the question of riveting, or the best and surest means of securing them together. On this part of the subject we have been widely astray, and it requires some skill, and no inconsiderable attention, in conducting the experiments, to convince the unreflecting portion of the public, and even some of our boiler makers, that the riveted joints were not stronger than the plate itself. At first sight this would appear the case, but a moment's reflection will soon convince us to the contrary, as, in punching holes along the edge of a plate, it is obvious that the plate must be weakened to the extent of the sectional areas punched out, and that it is next to impossible, under the circumstances, to retain the same strength in the material after such diminution has been effected, as existed in the previously solid plate. This was clearly demonstrated by a series of experiments, which took place some years since, and in which the strength of almost every description of riveted joints was determined by tearing them directly asunder. The results obtained from these experiments were conclusive, as regards the relative strength of riveted joints and the solid plates. In two different kinds of joints—double and single riveted—the strength was found to be, in the ratio of the plate, as the numbers 100, 70 and 56.

"Assuming the strength of the plate to be	100
The strength of a double riveted joint would be, after allowing for the adhesion of the surfaces of the plate	70
And the strength of a single riveted joint	56

"These proportions of the relative strengths of plates and joints may, therefore, in practice be safely taken as the standard value, in the construction of vessels required to be steam and water tight, and subjected to pressure varying from 10 lbs to 100 lbs. on the square inch.

"In the construction of boilers, exposed to severe internal pressure, it is desirable to establish such forms, and so to dispose the material as to apply the greatest strength in the direction of the greatest strain; and in order to accomplish this, it will be necessary to consider whether the same arrangement be required for all diameters, or whether the form as well as the disposition of the plates should not be changed. To determine these questions in cylindrical boilers, recourse must be had to experiment, or such deduction as may apply to any given case, and such as is founded upon unerring data, derived from experimental research. On this head I am fortunate in having before me the calculations of Professor W. R. Johnson, of the Franklin Institute of America, whose inquiries into the strength of cylindrical boilers are of great value, and from which the following short abstract may be useful.

"1st. To know the force which tends to burst a cylindrical vessel in the longitudinal direction, or, in other words, to separate the head from the curved sides, we have only to consider the actual area of the head, and to multiply the units of surface by the number of units of force applied to each superficial unit. This will give the total *divellent* force in that direction.

"To counteract this, we have, or may be conceived to have, the tenacity of as many longitudinal bars as there are lineal units in the circumference of the cylinder. The united strength of these bars constitutes the total retaining or *quiescent* force, and at the moment when rupture is about to take place the divellent and the quiescent forces must obviously be equal.

"2d. To ascertain the amount of force which tends to rupture the cylinder along the curved side, or rather along the opposite sides, we may regard the pressure as applied, through the whole breadth of the cylinder, upon each lineal unit of the diameter. Hence the total amount of force which would tend to divide the cylinder in halves, by separating it along two lines, on opposite sides, would be represented by multiplying the diameter by the force exerted on each unit of surface, and this product by the length of the cylinder. But even without regarding the length, we may consider the force requisite to rupture a single band in the direction now supposed, and of one lineal unit in breadth; since it obviously makes no difference whether the cylinder be long or short, in respect to the ease or difficulty of separating the sides. The divellent force in this direction is, therefore, truly represented by the diameter multiplied by the pressure per unit of surface. The retaining or quiescent force, in the same direction is only the strength or tenacity of the two opposite sides of the supposed bond. Here also, at the moment when a rupture is about to occur, the divellent force must exactly equal the quiescent force.

"Mr. Johnson then goes on to show that, as the diameter is increased, the product of the diameter and the force or pressure per unit of surface, are increased in the same ratio. This truth I shall endeavor to prove; as, also, that, as the diameter of any cylindrical vessel is increased, the thickness of the metal must also be increased in the exact ratio of the increase of the diameter: the pressure, or as Mr. Johnson calls it, the divellent force, being the same when the diameter of a boiler is increased, it must be borne in mind that the area of the ends is also increased, not in the ratio of the diameter but in the ratio of the square of the diameter: and it will be seen that instead of the force being doubled, as is the case in the direction of the diameter and circumference, it is quadrupled upon the ends, or, what is the same thing, a cylinder double the diameter of another cylinder has to sustain four times the pressure in the longitudinal direction. The retaining force of the thickness of the metal of a cylindrical boiler does not, however, increase in the same ratio as the area of the circle, but simply in the ratio of the diameter; consequently, the thickness of the metal will require to be increased in the same ratio as the diameter is increased. From this it appears, that the tendency to rupture by blowing out the ends of a cylindrical boiler will not be greater in this direction than it is in any other direction; we may therefore safely conclude, since we have seen that the tendency to rupture increases in both directions in the ratio of the diameter, that any deviation from that law, as regards the thickness of the plates, would not increase the strength of the boiler.

"I have been led to these inquiries from the circumstance that Mr. Johnson appears to reason on the supposition that there are no joints in the plates, and that the tenacity of the iron is equal to 60,000 lbs.—rather more than 26 tons to the square inch. Now, we have shown by the results of the experiments already adduced, that ordinary boiler plates will not bear more than 23 tons to the square inch; and, as nearly one third of the material is punched out for the reception of the rivets, we must still further reduce the strength, and take 15 tons or about 34,000 lbs.* on the square inch as the tenacity of the material or the pressure at which a boiler would burst.

"This I should consider in practice as the maximum power of resistance of boiler plates in their riveted state, and I will now endeavor to show you in a very concise, and I trust not uninteresting investigation, the bearing power of boilers, and the pressure at which they can be worked with safety. It has been stated that the strength of cylindrical boilers, when taken in the direction of their circumference, is in the ratio of their diameters, and when taken in the direction of the ends, as the squares of the diameters,—a proposition which it will not be difficult to demonstrate, as applicable to every description of boiler of the cylindrical form. It will be seen, however, that the strain is not exactly the same in every direction, and that there is actually less upon the material in the longitudinal direction than there is upon the circumference. For example, let us take two boilers, one three feet diameter and the other six feet, and suppose each to be subject to a pressure of 40 lbs. on the square inch. In this condition, it is evident that the area or number of square inches in the end of a three-feet boiler is, to that of the area of the six-feet boiler, as 1 to 4; and, by a common process of arithmetic, it will be found that the edges of the plates forming the cylindrical part of the three-feet boiler are subject (at 40 lbs. on the square inch) to a pressure of 40,712 lbs., upwards of 18 tons: whereas the plates of the six-feet boiler have to sustain a pressure of 162,848 lbs., or 72 tons, which is quadruple the force to which the boiler only one half the diameter is exposed; and the circumference being only as 2 to 1, there is necessarily double the strain upon the cylindrical plates of the large boiler. Now this is not the case with the other parts of the boiler, as the circumference of a cylinder increases only in the ratio of the diameter; consequently, the pressure, instead of being increased in the ratio of the square of the diameter, as shown in the ends, is only doubled, the circumference of the six-feet boiler being twice that of the three-feet boiler.

"Let us for the sake of illustration, suppose the two cylindrical boilers, such as we have described, to be divided into a series of hoops of one inch in width; and, taking one of these hoops in the three-feet boiler, we shall find it exposed, at a pressure of 40 lbs. on the square inch, to a force of 1,440 lbs., acting on each side of a line drawn through the axis of a cylinder 36 inches diameter and 1 inch in depth, and which line forms the diameter of the circle. Now, this force causes a strain upon the points *a a* in the direction of the arrows in the annexed diagram of the three-feet circle, of 720 lbs., and, assuming the pressure to be increased till the force becomes equal to the tenacity or retaining powers of the iron at *a a*, it is evident, in this state of the equilibrium of the two forces, that the least preponderance on the side of the internal pressure would insure fracture. And suppose we take the plates of which the boiler is composed at one quarter of an inch thick, and the ultimate strength at 34,000 lbs. on the square inch, we shall have $\frac{24,000}{36 \times 2} = 472$ per square inch, as the bursting pressure of the boiler. Again, as the forces in this direction are not as the squares, but simply as the diameters, it is clear that at 40 lbs. on the square inch we have in a hoop an inch in depth, or that portion of a cylinder whose diameter is six feet, exactly double the force applied to the points *b b*, which was acting on the points *a a*, in the diameter of three feet. Now, assuming the plates to be a quarter of an inch thick, as in the three-feet boiler, it follows, if the forces at the same pressure be doubled in the large cylinder, that the thickness of the plates must also be doubled in order to sustain the same pressure with equal security; or what is the same thing, the six-feet boiler must be worked at half the pressure, in order to insure the same degree of safety as attained in the three-feet boiler at double the pressure. From these facts it may be useful to know, that boilers having increased dimensions should also have increased strength in the ratio of their diameters; or, in other words, the plates of a six-feet boiler should be double the thickness of the plates of a three-feet boiler, and so on in proportion as the diameter is increased.

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* By experiment it is found that the strength of the riveted joints of boilers is only about one-half the strength of the plate itself; but taking into consideration the crossing of the joints, 34,000 lbs. may reasonably be taken as the tenacity of the riveted plates, or the bursting pressure of a cylindrical boiler.

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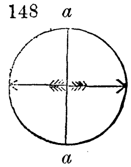

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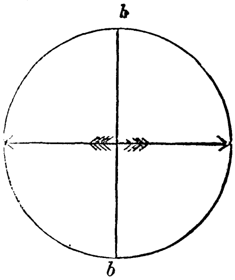

"The relative power of force applied to cylinders of different diameters becomes more strikingly apparent when we reduce them to their equivalents of strain per square inch, as applied to the ends and circumference of the boiler respectively. In the three-feet boiler, working at 40 lbs. pressure, we have a force equal to 720 lbs. upon an inch width of plate, and one quarter of an inch thick, or 720 by 4 = 2,880 lbs., the force per square inch upon every point of the circumference of the boiler. Let us now compare this with the actual strength of the riveted plates themselves, which, taken as before, at 34,000 lbs. on the square inch, we arrive at the ratio of pressure as applied to the strength of the circumference, as 2,880 to 34,000, nearly as 1 to 12, or 472 lbs. per square inch, as the ultimate strength of the riveted plates.

"These deductions appear to be true in every case as regards the resisting powers of cylindrical boilers to a force radiating in every direction from the axis towards the circumference; but the same reasoning is, however, not maintained when applied to the ends, or, to speak technically, to the angle iron and riveting, where the ends are attached to the circumference. Now, to prove this, let us take the three-feet boiler, where we have 113 inches in the circumference; and upon this circular line of connection we have, at 40 lbs. to the square inch, to sustain a pressure of 18 tons, which is equal to a strain of 360 lbs., acting longitudinally upon every inch of the circumference. Apply the same force to a six-feet boiler, with a circumference or line of connection equal to 226 inches, and we shall find it exposed to exactly four times the force, or 72 tons; but, in this case, it must be borne in mind, that the circumference is doubled, and consequently the strain, instead of being in the quadruple ratio, is only doubled, or a force equal to 720 lbs. acting longitudinally, as before, upon every inch of the circumference of the boiler. From these facts we come to the conclusion, that the strength of cylindrical boilers is in the ratio of their diameters if taken in the line of curvature, and as the squares of the diameters as applied to the ends or their sectional area; and that all descriptions of cylindrical tubes, to bear the same pressure, must be increased in strength in the direction of their circumference simply as their diameters, and in the direction of the ends as the squares of the diameters.

"Again, if we refer to the comparative merits of the plates composing cylindrical vessels subjected to internal pressure, they will be found in this anomalous condition, that the strength in their longitudinal direction is twice that of the plates in the curvilinear direction. This appears by a comparison of the two forces, wherein we have shown that the ends of the three-feet boiler, at 40 lbs. internal pressure, sustain 360 lbs. of longitudinal strain upon each inch of a plate a quarter of an inch thick; whereas the same thickness of plates has to bear in the curvilinear direction a strain of 720 lbs. This difference of strain is a difficulty not easily overcome; and all that we can accom-

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plish in this case will be to exercise a sound judgment in crossing the joints, in the quality of the workmanship, and the distribution of the material. For the attainment of these objects, the following table, which exhibits the proportionate strength of cylindrical boilers from three to eight feet in diameter, may be useful.

"*Table of equal Strengths in Cylindrical Boilers from* 3 *to* 8 *feet diameter, showing the thickness of metal in each respectively, at a pressure of* 450 *lbs. to the square inch.*

Diameter of Boilers.		Bursting Pressure equivalent to the ultimate strength of the riveted Joints, as deduced from experiment, 34,000 lbs. to the square inch.	Thickness of the Plates in Decimal parts of an Inch.
Ft.	Inch.		
3	0	450 lbs.	·250
3	6	—	·291
4	0	—	·333
4	6	—	·376
5	0	—	·416
5	6	—	·458
6	0	—	·500
6	6	—	·541
7	0	—	·583
7	6	—	·625
8	0	—	·666

"Boilers of the simple form, and without internal flues, are subjected only to one species of strain; but those constructed with internal flues are exposed to the same tensile force which pervades the simple form; and, further, to the force of compression which tends to collapse or crush the material of the internal flues. In the cylindrical boiler with round flues, the forces are diverging from the central axis as regards the outer shell, and converging as applied to every separate flue which the boiler contains.

"These two forces in a steam boiler are in constant operation; the tendency of the one being to tear up the external plates and force out the ends, and the other to destroy the form and to force the material into the central area of the flues. These two forces operate widely different upon the resisting powers of the boiler, which, taken in the direction of its exterior envelope, has to resist a tensile strain operating in every direction from within, and the internal flues acting as an arch offer a powerful resistance to compression from without. It might be instructive as well as interesting to exhibit the nature of these powers, and determine the law by which vessels of this description are retained in shape, but this can only be done by experiment; and as these experiments would have to be conducted upon a large scale, and with great accuracy, in order to arrive at satisfactory results, we must abandon the idea for the present, and content ourselves with such information as we already possess. 'At some future period I may possibly devote my attention to this subject. It is one of great importance; and a series of well-conducted experiments would, I make no doubt, supply valuable data in the varied requirements of boiler construction, and their comparative powers of resistance to the united force of tension and compression.'—(*Mr. Fairbairn's Lecture.*)

"From the existing state of our knowledge, we must rest satisfied with the fact, that the resisting powers of cylindrical flues to compression will be directly as their diameters; and we may therefore conclude that a circular flue 18 inches in diameter will resist double the pressure of one 3 feet in diameter. Hence it follows that the resistance of wrought iron plates of the circular form is to the force of compression as their diameters—the same, but with greatly diminished powers, as compared with the resistance of wrought iron cylindrical plates to tension.

"To show the amount of strain upon a high-pressure boiler 30 feet long, 6 feet diameter, having two centre flues, each 2 feet 3 inches diameter, working at a pressure of 50 lbs. on the square inch, we have only to multiply the number of square feet of sur face, 1,030, exposed to pressure, by 321, and we have the force of 3,319 tons, which a boiler of these dimensions has to sustain. I mention this to show that the statistics of pressure when worked out are not only curious in themselves, but instructive as regards a knowledge of the retaining powers of vessels so extensively used, and on which the bread of thousands depends. To pursue the subject a little further, let us suppose the pressure to be at 450 lbs. on the square inch, which a well-constructed boiler of this description will bear before it bursts, and we have the enormous force of 29,871, or nearly 30,000 tons, bottled up within a cylinder 30 feet long and 6 feet diameter.

"This is, however, inconsiderable when compared with the locomotive and some

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marine boilers, which, from the number of tubes, present a much larger extent of surface to pressure. Locomotive engines are usually worked at 80 to 100 lbs. on the inch, and, taking one of the usual construction, we shall find, at 100 lbs. on the inch, that it rushes forward on the rail with a pent-up force within its interior of nearly 60,000 tons, which is rather increased than diminished at an accelerated speed.

"In a stationary boiler charged with steam at a given pressure, it is evident that the forces are in perfect equilibrium, and, the strain being the same in all directions, there will be no tendency to motion. Supposing, however, this equilibrium to be destroyed by accumulative pressure till rupture ensues, it then follows that, the forces in one direction having ceased, the other in an opposite direction, being active, would project the boiler from its seat with a force equal to that which is discharged through the orifice of rupture. The direction of motion would depend upon the position of the ruptured part. If in the line of the centre of gravity, motion would ensue in that direction; if out of that line, an oblique or rotatory motion round the centre of gravity would be the result.

"The velocity or quantity of motion produced in one direction would be equal to the intensity or quantity lost; and the velocity with which the body would move would be in the ratio of the impulsive force, or the quantity lost. Therefore, the quantity of motion gained by an exploded boiler in one direction will be as its weight and the quantity lost in that direction. These definitions are, however, more in the province of the mathematician, and may easily be computed from well-known formulæ on the laws of motion.

"We now come to the rectangular forms, or flat surfaces, which are not so well calculated to resist pressure. Of these we may instance the fire-box of the locomotive boiler, the sides and flues of marine boilers—the latter of which, by the by, are now superseded by those of the tubular form—and the flat ends of the cylindrical boilers, and others of weaker construction.

"The locomotive boiler is frequently worked up to a pressure of 120 lbs. on the square inch, and at times, when rising steep gradients, I have known the steam nearly as high as 200 lbs. on the inch. In a locomotive boiler subject to such an enormous working pressure, it requires the utmost care and attention on the part of the engineer to satisfy himself that the flat surfaces of the fire-box are capable of resisting that pressure, and that every part of the boiler is so nearly balanced in its powers of resistance, as that, when one part is at the point of rupture, every other part is on the point of yielding to the same uniform force. This appears to be an important consideration in mechanical constructions of every kind, as any material applied for the security of one part of a vessel subject to uniform pressure, whilst another part is left weak, is so much material thrown away; and in stationary boilers, or in moving bodies, such as locomotive engines and steam vessels, it is absolutely injurious, at least so far as the parts are disproportionate to each other, and the extra weight when maintained in motion becomes an expensive and unwieldy encumbrance. A knowledge of the strength of materials used, judicious care, and the exercise of sound judgment in its distribution, are therefore some of the most essential qualifications of the practical engineer. Our limited knowledge and defective principles of construction are manifest from the numerous abortions which exist, and, although I am free to communicate all that I know on the subject, I nevertheless find myself deficient in many of the requirements necessary for the attainment of sound principles of construction.

"Reverting to the question more immediately under consideration, it is, however, essential to give the requisite security to those parts which, if left unsupported, would involve the public as well as ourselves in the greatest jeopardy.

"The greater portion of the fire-boxes of locomotive boilers, as before noticed, have the rectangular form, and, in order to economize heat and give space for the furnace, it becomes necessary to have an interior and exterior shell.

"That which contains the furnace is generally made of copper, firmly united by rivets, and the exterior shell, which covers the fire-box, is made of iron and united by rivets in the same way as the copper fire-box. Now these plates would of themselves be totally inadequate, unless supported by riveted stays to sustain the pressure. In fact, with one-tenth the strain, the copper fire-box would be forced inwards upon the furnace and the external shell bulged outwards, and with every change of force these two flat surfaces would move backwards and forwards, like the sides of an inflated bladder, at the point of rupture. To prevent this, and give the large flat surfaces an approximate degree of strength with the other parts of the boiler, wrought iron or copper stays, one inch thick, are introduced; they are first screwed into the iron and copper on both sides to prevent leakage, and then firmly riveted to the interior and exterior plates. These stays are about six inches asunder, forming a series of squares, and each of them will resist a strain of about fifteen tons before it breaks.

"Let us now suppose the greatest pressure contained in the boiler to be 200 lbs. on the square inch, and we have 6 × 6 × 200 = 7,200 lbs., or $3\frac{1}{4}$ tons, the force applied to a square of 36 inches. Now as these squares are supported by four stays, each capable of sustaining fifteen tons, we have 4 × 15 = 60 tons as the resisting powers of the stays, but the pressure is not divided amongst all the four, but each stay has to sustain that pressure; consequently the ratio of strength to the pressure will be as $4\frac{1}{2}$ to 1 nearly, which is a very fair proportion for the resisting power of that part.

"We have treated of the sides, but the top of the fire-box and the ends have also to be protected, and there being no plate but the circular top of the boiler from which to attach stays, it has been found more convenient and equally advantageous to secure those parts by a series of strong wrought-iron bars, from which the roof of the fire-box is suspended, and which effectually prevent it from being forced down upon the fire. It will not be necessary to go into the calculations of those parts; they are, when riveted to the domo or roof, of sufficient strength to resist a pressure of 300 to 400 lbs. on the square inch. This is, however, generally speaking, the weakest part of the boiler, with the exception, probably, of the flat end above the tubes in the smoke-box, if not carefully stayed.

"In the flat ends of cylindrical boilers, and those of the marine principle, the same rule applies as regards construction, and a due proportion of the parts, as in those of the locomotive boilers, must be closely adhered to. Every description of boiler used in manufactories, or on board of steamers, should in my opinion be constructed to a bursting pressure of 400 to 500 lbs. on the square inch; and locomotive engine boilers, which are subjected to a much severer duty, to a bursting pressure of 600 to 700 lbs.

"It now only remains for me to state that internal flues, such as contain the furnace in the interior of the boiler, should be kept as near as possible to the cylindrical form, and as wrought-iron will yield to a force tending to crush it about one half of what would tear it asunder, the flues should in no case exceed one half the diameter of the boiler: and with the same thickness of plates they may be considered equally safe with the other parts. But the force of compression is so different from that of tension, that I should advise the diameter of the internal flues to be in the ratio of 1 to $2\frac{1}{2}$ instead of 1 to 2 of the diameter of the boiler.

"I will not trouble you with a description of the haycock, hemispherical, and wagon-shape boilers; they are all bad as respects their powers of resistance, and ought to be entirely disused: I shall congratulate the public when they disappear from the list of those constructions having the confidence of the public, and the consideration of the man of science or the practical engineer.

"In conclusion, I have to recommend attention to a few simple rules, which, if carefully observed, will lead to the most satisfactory results. To construct boilers as nearly as possible, of maximum strength, I have already observed they should be of the cylindrical form; and where flat ends are used, they should be composed of plates one half thicker than those which form the circumference. The flues, if two in number, to be of the same thickness as the exterior shell; and the flat ends to be carefully stayed with gussets of triangular plates and angle iron, firmly connecting them with the circumference, as per annexed sketch.

"The use of gussets I earnestly recommend, as being infinitely superior to, and more certain in their action and retaining powers, than stay rods. Gussets, when used, should be placed in lines diverging from the centre of the boilers, and made as long as the position of the flues and other circumstances in the construction will admit. They are of great value in retaining the ends in shape, and may safely be relied upon as imparting an equality of strength to every part of the structure. With these observations, I would direct attention to the facts I have endeavored to inculcate. You will, I am persuaded, find them useful; and I trust the object contemplated by the committee of your valuable Institution will be fully attained, in the acquisition of greater security and a more perfect principle of construction."*

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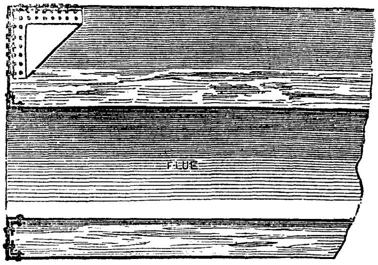

Boilers (*Explosions of*).—"In a former lecture I endeavored to explain the principles on which boilers should be constructed, and the laws which govern the strength and other properties of these important vessels. The subject of construction is one of vast importance, and those forms which give the greatest security with the least quantity of material, may be considered as the safest examples for imitation—the true elements of construction. Boilers, of all other vessels, require, in the variety of their conditions shapes, and dimensions, the study of the philosopher as well as the hands of the mechanic. They contain, within comparatively narrow bounds, a force which, if properly governed, will propel the largest and most stately vessel against wind and tide; perform the work of a thousand hands, and drive a hundred cars loaded with hundreds of tons, at the speed of the swiftest race horse, from one extremity of the kingdom to the other. They do all this and more; they impart heat and comfort to our dwellings, —are essential for the requirements of our domestic arrangements,—and under the control of judicious management, will advance the interests of commerce, and contribute to the enjoyments of civilized existence.

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* Lecture at Leeds Mechanics' Institution, by William Fairbairn, Esq., C. E. F. R. S. and Corresp. Member of the Institute of France.

"Reverse the picture, and entrust the construction and management to the hands of incapacity and ignorance, or the reckless folly and hardihood of fancied security, and death and destruction follow as a result. When the mischief is done, we then begin to guess at the causes, and to lament the inconsiderate confidence which led to the employment of incompetency, and all those errors of judgment which invariably present themselves, not before, but after the event. How often do we hear of the most lamentable accidents terminating in the destruction of life and property, and how often do we lament (when too late) the causes which led to those frightful catastrophes! All these accidents might be prevented, and, instead of using steam, which we now do in our manufactories, at a pressure of 5 to 20 lbs. on the square inch, we might with equal safety use it, and enjoy the advantage of its superior economy, at 60 lbs. on the inch. It shall be my duty to point out how this may be accomplished, and I hope in these endeavors to have the support of every well wisher for increased security to the public, and enlarged economy in the varied requirements of the use of steam.

"Before I attempt a solution of this difficult question, I would first direct attention to a few facts which bear more directly upon the question now at issue.

"Various notions are entertained as to the causes of boiler explosions, and scientific men are not always agreed as to whether they arise from excessive pressure due to the accumulation of heat, or to some other cause, such as the explosion of hydrogen gas, generated by the decomposition of water suddenly thrown on heated plates, of which we have an exceedingly indefinite conception. That of the decomposition of water is, I believe, a somewhat prevalent opinion, but I apprehend it cannot be the invariable cause, inasmuch as in that case we must assume the boiler to be nearly empty of water, and the plates over the furnace red hot.

"It is not unreasonable to suppose that a force of such sudden origin, and so immediate and destructive in its effects, should suggest the presence of an explosive mixture; but I think it will be difficult, if not impossible, to account for the accumulation of a sufficient quantity of hydrogen, without the presence of oxygen and other gases, in their due proportions, to form an explosive compound. Now as these equivalents cannot be generated all at once by the simple decomposition of water (admitting, for the moment, that the water is decomposed), we must look for some other cause for the fatal and destructive accidents which of late years have become so prevalent.

"In treating of this subject, I hope to show not only what are the probable causes of explosions, but, what appears equally important, what are not the causes. So many theories (some of them exceedingly problematical) have been brought forward on the occasion of disastrous explosions, that it requires the utmost care and attention to circumstances before they are generally admitted. To acquire satisfactory evidence as to the precise condition of the boiler and furnace before an explosion, is next to impossible, as most frequently the parties in charge, and from whose mismanagement and neglect we may, in many cases, date the origin of the occurrence, are the first to become the victims of their own indiscretion, and we can only judge from the havoc and devastation that ensues as to the immediate cause of the event.

"From this it follows that, in many of the explosions on record, few, if any, of the real circumstances of the case are made known, and we are left to draw conclusions from the appearances of the ruptured parts, and the terrific consequences which too frequently follow as a result. This want of evidence as to the precise condition of a boiler, with all its valves and mountings, preceding an explosion, is much to be regretted, as it causes a degree of mystery to surround the whole transaction; and the vague and sometimes inaccurate testimony of witnesses but too often baffles all attempts at research, and creates additional cause of alarm to all those exposed to the occurrence of similar dangers.

"In the discussion of this subject I shall, however, endeavor to trace, from a number of examples in which I have been personally engaged, and from others which have come to my knowledge, the causes which have led to those disastrous effects; and provided I am successful in the discovery of the true origin of the majority of those occurrences, we shall have less difficulty in devising and applying the necessary remedies for their prevention.

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"In my attempts to ascertain facts by a course of reasoning which I shall have to follow in this investigation, I wish it to be understood that it is not my intention to raise doubts and fears, in the public mind, calculated to arrest the progress of commercial enterprise, or to cripple the energies of mechanical skill. On the contrary, I am most anxious to promote the advancement of the useful arts, to increase our confidence in the application of increased pressure, and to secure within moderate bounds the economical and useful employment of one of the most powerful agents ever known in the history of practical science. My object in this inquiry will, therefore, be to enlarge our sphere of action by a more comprehensive knowledge of the subject on which it treats; to induce greater caution along with improved construction; and to insure confidence in all those requirements essential to the public security.

"For the full consideration of this subject, it will be necessary to divide it into the following heads;—

"1st. Boiler explosions arising from accumulated internal pressure.
"2d. Explosions from deficiency of water.
"3d. Explosions produced from collapse.
"4th. Explosions from defective construction.
"5th. Explosions arising from mismanagement or ignorance; and
"6th. The remedies applicable for the prevention of these accidents.

"*1st. Boiler explosions arising from accumulated internal pressure.*

"In nine cases out of ten a continuous increasing pressure of steam, without the means of escape, is probably the immediate cause of explosion; in some instances it arises from deficiency of water, but accidents of this kind are comparatively few in number, as we often find, in tracing the causes, that they have their origin in undue pressure, emanating from progressive accumulation of steam of great force and density. Let us take an example, and we shall find that a boiler under the influence of a furnace in active combustion will generate an immense quantity of steam; and unless this is carried off by the safety-valve or the usual channels when so generated, the greatest danger may be apprehended by the continuous increase of pressure that is taking place within the boiler. Suppose that, from some cause, the steam thus accumulated does not escape with the same rapidity with which it is generated,—that the safety-valves are either inadequate to the full discharge of the surplus steam, or that they are entirely inoperative, which is sometimes the case,—and we have at once the clue to the injurious consequences which, as a matter of fact, are sure to follow. The event may be procrastinated, and repeated trials of the antagonistic forces from within, and the resistance of the plates from without, may occur without any apparent danger, but these experiments often repeated will at length injure the resisting powers of the material, and the ultimatum will be the arrival of the fatal moment when the balance of the two forces is destroyed, and explosion ensues. How very often do we find this to be the true cause of accidents arising from extreme internal pressure, and how very easily these accidents might be avoided by the attachment of proper safety-valves, to allow the steam to escape and relieve the boiler of those severe trials which ultimately lead to destruction! If a boiler whose generative power is equal to 100, be worked at a pressure of 10 lbs. on the square inch, the area of the safety-valves should also be equal to 100, in order to prevent a continuous increase of pressure; or, in case of the adhesion of any of the valves, it is desirable that their areas should, collectively, be equal to 100. If two or more valves are used, 100 or 120 would then be the measure of outlet.* Under these precautions, and with a boiler so constructed, the risk of accident is greatly diminished; and, provided one of the valves is kept in working order beyond the reach of interference by the engineer, *or any other person*, we may venture to assume that the means of escape are at hand, irrespective of the temporary stoppage of the usual channels for carrying off the steam.

"So many accidents have occurred from this cause—the defective state of the safety-valves—that I must request attention whilst I enumerate a few of the most prominent cases that have come before me. In the year 1845 a tremendous explosion took place at a cotton mill in Bolton. The boilers, three in number, were situated under the mill, and, from the unequal capacity and imperfect state of the safety-valves (as they were probably fast), a terrible explosion of the weakest boiler took place, which tore up the plates along the bottom, and, the steam having no outlet at the top, not only burst out the end next the furnace, demolishing the building in that direction, but, tearing up the top on the opposite side, the boiler was projected upwards in an oblique direction, carrying the floors, walls, and every other obstruction before it; ultimately it lodged itself across the railway at some distance from the building. Looking at the disastrous consequences of this accident, and the number of persons (from 16 to 18) who lost their lives on the occasion, it became a subject of deep interest to the community that a close investigation should immediately be instituted, and a recommendation followed that every precaution should be used in the construction as well as the management of boilers.

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*This may be stated in other words, viz., that the generative powers of a boiler being equal to a given number of square inches of area, say 50, the area of the safety-valve should also be 50.

"The next fatal occurrence on record in this district was a boiler at Ashton-under-Lyne, which exploded under similar circumstances, namely, from excessive interior pressure, when four or five lives were lost; and again at Hyde, where a similar accident occurred from the same cause, which was afterwards traced to the insane act of the stoker or engineer, who prevented all means for the steam to escape by tying down the safety-valve.

"There was a boiler explosion at Malaga, in Spain, some years since, and my reason for noticing it in this place is to show that explosions may be apprehended from other causes than those enumerated in the divisions of this inquiry, and one of these is *incrustation.* Dr. Ritterbrandt says, in a paper read before the Institution of Civil Engineers by an eminent chemist, Mr. West—'That a sudden evolution of steam under circumstances of incrustation is no uncommon occurrence.' In several instances I have known this to be the case, particularly in marine boilers, where the incrustation from salt water becomes a serious grievance, either as regards the duration of the boiler, or the economy of fuel.

"If it were supposed, as Dr. Ritterbrandt observes, that the boiler was incrusted to the extent of half an inch, it would at once be seen that nothing was more easy than to heat the boiler strongly, even to a red heat, without the immediate contact of water. Under these circumstances, the hardened deposits, being firmly attached to the plates, and forming an imperfect conductor of heat, would tend greatly to increase the temperature of the iron; and the difference of temperature, thus induced between the iron and the incrustation, and the greater expansibility of the iron, would cause the incrustation to separate from the plates, and the water rushing in between them would generate a considerable charge of highly elastic steam, and thus endanger the security of the boilers.

"These phenomena were singularly exemplified in the Malaga explosion, which in thus described by Mr. Hick;—'I have ascertained that a very thick incrustation of salt was formed on the lower part of the boiler, immediately over the fire, and so far as it extended the plates appear to have been red hot, being thereby much weakened, and hence the explosion. The ordinary working pressure of the boiler is 130 lbs. per square inch, and perhaps at the time of the explosion very much above that pressure, as there was only one small safety-valve of two and a-half inches diameter. The boiler was only two feet six inches diameter, and twenty feet long.'

"Incrustation, exclusive of being dangerous, is attended with great expense and injury to the boiler by its removal. In the case of the transatlantic, oriental, or other long sea-going vessels, even after the use of brine-pumps, blowing out, &c., a very large amount of incrustation is formed, and considerable sums of money are expended each voyage to remove it.

"Other explosions of a more recent date are those which occurred at Bradford and Halifax. They are still fresh in the recollection of the public mind, and are so well known as not to require notice in this place.

"I cannot, however, leave this part of the subject without reverting to an accident which occurred on the Lancashire and Yorkshire Railway, which had its origin in the same cause—excessive internal pressure. This accident is the more peculiar as it led to a long mathematical disquisition as to the nature of the forces which produced results at once curious and interesting. The conclusions which I arrived at, although *practically right, were, however, considered by some mathematically wrong,* as they were firmly combated by several eminent mathematicians; but notwithstanding the number of algebraic formulas and the learned discussions of my friends on that occasion, I have been unable to change the opinions I then formed, for others more conclusive.

"The accident here alluded to occurred to the 'Irk' locomotive engine, which, in February, 1745, blew up and killed the driver, the stoker, and another person who was standing near the spot at the time. A great difference of opinion as to the cause of this accident was prevalent in the minds of those who witnessed the explosion, some attributing it to a crack in the copper fire-box, and others to the weakness of the stays over the top. Neither of these opinions was, however, correct, as it was afterwards demonstrated that the material was not only entirely free from cracks and flaws, but the stays were proved sufficient to resist a pressure of 150 to 200 lbs. on the square inch. The true cause was afterwards ascertained to arise from the fastening down of the safety-valve of the engine (an active fire being in operation under the boiler at the time), which was under the shed, with the steam up, ready to start with the early morning train. The effect of this was the forcing down of the top of the copper fire-box upon the blazing embers of the furnace, which, acting upon the principle of the rocket, elevated the boiler and engine of 20 tons weight to a height of 30 feet, which, in its ascent made a summerset in the air, passed through the roof of the shed, and ultimately landed at a distance of 60 yards from its original position. The question which excited most interest, was the absolute force required to fracture the fire-box, its peculiar properties when once liberated, and the elastic or continuous powers in operation which forced the engine from its place to an elevation of 30 feet from the position in which it stood. An elaborate mathematical discussion ensued relative to the nature of these forces, which ended in the opinion that a pressure sufficient to rupture the fire-box, was, by its continuous action, sufficient to elevate the boiler and produce the results which followed. Another reason was assigned, namely, that an accumulated force of elastic vapor, at a high temperature, with no outlet through the valves, having suddenly burst upon the glowing embers of the furnace, would charge the products of combustion with their equivalents of oxygen, and hence explosion followed. Whether one or both of these two causes were in operation is probably difficult to determine; at all events, we have in many instances precisely the same results produced from similar causes, and unless greater precaution is used in the prevention of excessive pressure, we may naturally expect a repetition of the same fatal consequences.

"The preventives against accidents of this kind are, well-constructed boilers of the strongest form, and duly proportioned safety valves; one under the immediate control of the engineer, and the other, as a reserve under the keeping of some competent authority.

"2*d. Explosions by deficiency of water.*

"This division of the subject requires the utmost care and attention, as the circumstance of boilers being short of water is no unusual occurrence. Imminent danger frequently arises from this cause; and it cannot be too forcibly impressed upon the minds of engineers, that there is no part of the apparatus constituting the mountings of a boiler which require greater attention—probably the safety-valves not excepted—than that which supplies it with water. A well-constructed pump, and self-acting feeders, when boilers are worked at a low pressure, are indispensable; and where the latter cannot be applied, the glass tubular gauge, steam, and water cocks must have more than ordinary attention.

"In a properly constructed boiler every part of the metal exposed to the direct action of the fire should be in immediate contact with the water, and, when proper provision is made to maintain the water at a sufficient height above the part of the plates so exposed, accidents can never occur from this cause.

"Should the water, however, get low from defects in the pump, or any stoppage of the regulating feed valves, and the plates over the furnace become red hot, we then risk the bursting of the boiler, even at the ordinary working pressure. We have no occasion, under such circumstances, to search for another cause, from the fact that the material when raised to a red-heat has lost about five-sixths of its strength, and a force of less than one-sixth will be found amply sufficient to bear down the plates direct upon the fire, or to burst the boiler.

"When a boiler becomes short of water, the first, and perhaps the most natural, action is to run to the feed valve, and pull it wide open. This certainly remedies the deficiency, but increases the danger, by suddenly pouring upon the incandescent plates a large body of water, which, coming in contact with a reservoir of intense heat, is calculated to produce highly elastic steam. This has been hitherto controverted by several eminent chemists and philosophers; but I make no doubt such is the case, unless the pressure has forced the plates into a concave shape, which for a time would retard the evaporization of the water when suddenly thrown upon them. Some curious experimental facts have been elicited on this subject, and those of M. Boutigny, and Professor Bowman, of King's College, London, show that a small quantity of water projected upon a hot plate does not touch it; that it forms itself into a globule surrounded with a thin film, and rolls about upon the plate without the least appearance of evaporation. A repulsive action takes place, and these phenomena are explained upon the supposition that the spheroid has a perfectly reflecting surface, and consequently the heat of the incandescent plate is reflected back upon it. What is, however, the most extraordinary in these experiments, is the fact that the globule, whilst rolling upon a red hot plate, never exceeds a temperature of about 204° of Fahr.; and in order to produce ebullition, it is necessary to cool the plate until the water begins to boil, when it is rapidly dissipated in steam.

"The experiments by the committee of the Franklin Institute on this subject, give some interesting and useful results. That committee found that the temperature at which clean iron vaporized drops of water was 334° of Fahr. The development of a repulsive force which I have endeavored to describe was, however, so rapid above that temperature, that drops which required but one second of time to disappear at the temperature of maximum evaporation, required 152 seconds when the metal was heated to 395° of Fahr. The committee go on to state that—'One ounce of water introduced into an iron bowl three-sixteenths of an inch thick, and supplied with heat by an oil-bath, at the temperature of 546°, was vaporized in fifteen seconds, while, at the initial temperature of 507°, that of the most rapid evaporization was thirteen seconds.'

"The cooling effect of the metal is here strikingly exemplified by the increased rapidity of the evaporization, which at a reduced temperature of 38° is effected in thirteen instead of fifteen seconds.

"This does not, however, hold good in every case, as an increased quantity of water, say from one-eighth of an ounce to two ounces, thrown upon heated plates, raised the temperature of vaporization from 460° to 600° Fahr.; thus clearly showing that the time required for the generation of explosive steam under these circumstances is attended with danger; and it may be doubted whether the ordinary safety valves may not be wholly inadequate for its escape.

"Numerous examples may be quoted to show that explosions from deficiency of water, although less frequent than those arising from undue pressure, are by no means uncommon. They are nevertheless comparatively few in number, and the preventives are good pumps, self-acting feeders (when they can be applied), and all those conveniences, such as water-cocks, water-gauges, floats, alarms, and other indicators of the loss and reduction of water in the boiler.

"3*d. Explosions produced from collapse.*

"Accidents from this cause can scarcely be called explosions, as they arise, not from internal force which bursts the boiler, but from the sudden action of a vacuum within it. In high pressure boilers, from their superior strength and circular form, these accidents seldom occur, and the low pressure boiler is effectually guarded against it by a valve which opens inwards by the pressure of the atmosphere whenever a vacuum occurs. In some cases a collapse of the internal flues of boilers has been known to take place, from a partial vacuum within, which, united to the pressure of the steam, has forced down the top and sides of the flue, and with fatal effect discharged the contents of the boiler into the ash-pit, and destroyed and scalded every thing before it. A circumstance of this kind occurred on the Thames on board the steamer *Victoria*, some years since, when a number of persons lost their lives, and serious injury was sustained in all parts of the vessel within reach of the steam. This accident could not, however, be called an explosion, but a collapse of the internal flues, which were of large dimensions, and the consequent discharge of large quantities of steam and water into the space occupied by the engines.

"One or two cases which bear more directly on this point, are, however, on record, and one of them, which took place in the Mold mines in Flintshire, was attended with explosion. The particulars, as given by Mr. John Taylor, will be found circumstantially recorded in the first volume of the *Philosophical Magazine.* This occurrence seems to prove that rarefaction produced in the flues of a high pressure boiler may determine an explosion. The boiler which exploded belonged to a set of three feeding the same engine; the fuel used was bituminous coal. The furnace doors of all three of the boilers had been opened, and the dampers of two had been closed, when a gust of flame was seen to issue from the mouth of the furnace of these latter, and was immediately followed by an explosion. The interior flue of this boiler was flattened from the sides, the flue and shell of the boiler remaining in their places, and the safety-valve upon the latter not being injured.

"Other similar cases of collapse might be stated, but as most of them have been attended by a defective supply of water in the boiler, the plates over the fire having become heated, they can scarcely be included in the category of this class of accidents, and more properly belong to those of which we have just treated,—explosions from a deficiency of water in the boiler.

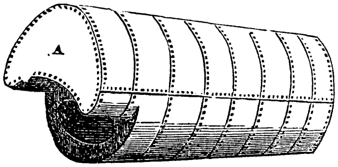
"It is, nevertheless, necessary to observe, that cases of collapse should be carefully guarded against, as the great source of danger is in the escape of hot water, which, with the steam generated by it produces death in one of its worst and most painful forms.

"The remedies for these accidents will be found in the vacuum valve, and careful construction in the form and strength of the flues.

"4*th. Explosions from defective construction.*

"This is, perhaps, one of the most important divisions that can possibly engage our attention, and on which it shall be my duty to enlarge. In a previous inquiry I have already shown the nature of the strain and the ultimate resistance which the material used in the construction of boilers is able to bear. We have not, however, in all cases shown the distribution and position in which that material should be placed in order to attain the maximum of strength, and afford to the public greater security in the resisting powers of vessels subject to severe and sometimes ruinous pressure. This is a subject of such importance that I shall be under the necessity of trespassing upon your time, in endeavoring to point out the advantages peculiar to form, and the use of a sound and perfect system of construction.

"For a number of years the haycock, hemispherical, and wagon-shaped boilers were those generally in use; and it was not until high pressure steam was first intro duced into Cornwall, that the cylindrical form with hemispherical ends, and the furnace under the boiler, came into use. Subsequently this gave way to the introduction of a large internal flue extending the whole length of the boiler, and in this the furnace was placed. For many years this was the best and most economical boiler in Cornwall, and its introduction into this country has effected great improvements in the economy of fuel as well as the strength of the boiler. Several attempts have been made to improve this boiler by cutting away one half of the end, in order to admit a larger furnace. This was first done by the Butterley Company, and it since has gone by the name of the Butterley boiler. This construction has the same defects as the haycock or *hemispherical* and wagon-shaped boilers: it is weak over the fire-place, and cannot well be strengthened without injury to the part A, *fig.* 151, of the boiler, from the vast number of stays necessary to suspend the part which forms the canopy of the furnace. Of late years a much greater improvement has, however, been effected by the double flue, B B, *fig.* 152, and double furnace boiler, which is now in general use, and has nearly superseded all the other constructions. It consists of the cylindrical form, varying from five to seven feet in diameter, with two flues which extend the whole length of the boiler; they are perfectly cylindrical, and of sufficient magnitude to admit a furnace in each. This boiler is the simplest, and probably the most effective, that has yet been constructed. It presents a large flue surface as the recipient of heat, and the double flues, when riveted to the flat ends, add greatly to the security and strength of those parts. It, moreover, admits of the new process of alternate firing, so highly conducive to perfect combustion, and the prevention of the nuisance of smoke.—*Fairbairn and Hetherington's patent of April* 30, 1844.



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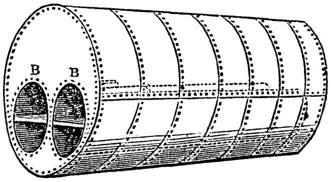

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"Another boiler, into which a number of small tubes are introduced, exhibits a powerful generator of steam, from the extent of its flue surface, and the facility with which the repairs can be effected. It does not present any greater security against explosion than the boiler with two flues, but its construction on the tubular system effects a great saving in space, and is otherwise productive of all the advantages of economy in the consumption of fuel and the prevention of smoke. This boiler is constructed with a large internal flue, divided in the middle, which admits of two fire-places and alternate firing. In the space which I call the mixing chamber, the products of combustion amalgamate, and are thus ignited before they enter the tubes, and from which they issue into the end flues, and from thence to the chimney in the usual way. In this latter construction it will be observed that the boiler is of the same form as the last, and contains the same elements of strength as the double-flue boiler, the only difference being a combination of the locomotive and marine tubular system, which contains a large absorbent heating surface in a small space.

"It will not be necessary to multiply examples of construction, as I have already described those which I consider best calculated to sustain severe pressure. At the same time, when the parts are judiciously and skilfully arranged, with a grate-bar surface well proportioned to the amount of flue-surface as the recipient, we may reasonably conclude that we are not far from the maximum of strength, including other important elements in the material and the consumption of fuel.

"The means necessary to be employed for the prevention of accidents in this department of the inquiry, are a knowledge of the principles of construction, and an acquaintance with the strength and properties of the materials used for that purpose.

"*5th. Explosions arising from mismanagement or ignorance.*

"To mismanagement, ignorance, and the misapplication of a few leading principles in connection with the use and application of steam, may be traced the great majority of accidents which from time to time occur. Many of these accidents, so fruitful of the destruction of property and human life, might be prevented if we had well constructed vessels, judiciously united to skill and competency in the management. To convey a few practical instructions to engineers, stokers, and engine-men, would be an undertaking of no great difficulty. A young man of ordinary capacity would learn all that is necessary in a few months; and if placed under competent instructors, he might be made acquainted with the properties of steam—its elastic force at different degrees of pressure—the advantages peculiar to sensitive and easy working safety valves—the necessity of cleanliness and keeping them in good working condition—the use of water gauges, fusion plugs, indicators, signals, &c., &c., connected with the supply and height of water in the boiler—the dangers to be apprehended from a scarcity of water—the danger of explosion when the engine is standing, or when the usual channels for relieving the boiler of its surplus steam are stoppod. All these are parts of elementary instruction which the stoker, as well as the engineer, should be acquainted with; and no proprietor of a mill, captain of a steamship, or superintendent of locomotives should give employment to any persons unless they can produce certificates of good behavior, and a knowledge of the elementary principles of their profession.

"If these precautions were adopted, greater care observed in the selection of men of skill and responsibility in the construction of boilers, and a more strict and rigid code of laws in the management, we might look forward with greater certainty to a considerable diminution, if not a prevention, of those calamitous events which so frequently plunge whole families into mourning by unexpected and instantaneous death.

"As an individual, I would cheerfully lend my best assistance to the development of a principle of instruction calculated to relieve the country of the ignorance which pervades that part of the community on which the lives of so many depend. A resolution on the part of those who employ persons of this description, and whose interests are so much at stake, to take only those whose knowledge and character come up to the requisite standard, *and pay for it,* would soon cause, from the economy of the management, and the increased security of their property, a very important change in all the requirements of the economy, as well as the application, of steam. How often do we find implements of danger, and vessels containing the elements of destruction, in the hands of the most ignorant and reckless practitioners, whose insensibility to danger, and total incompetency to judge of its presence, render them above all others the most unfit to be employed. And why? Because they are the very persons, from their defective knowledge, to increase the danger and aggravate the evils they were selected to prevent. It is not the first time that engineers, to secure (if I may use the expression) an insane pressure, have fastened the safety valves, and screwed down the steam valve, closing every outlet, without ever thinking of the fire that was blazing under the boiler. Under such circumstances what could be expected but a blow up? A madman rushing with a lighted match into a powder magazine could not act with greater insanity. Such, however, has been the case, and all arising from want of thought, or, what is worse, from the total absence of knowledge, which it was the duty of his employer as well as himself to have possessed.

"I have on former occasions stated that I am not an advocate for legislative interference either in the construction or management of boilers; but, seeing the dangerous tendency of these vessels when placed under the control of ignorance and incapacity, I would forego many considerations to encourage a more judicious and intelligent class of men than has hitherto been employed in the care and management of steam and the steam engine. The reforms necessary to be introduced may be made by the owners of steam engines, steamboats, railways, and others engaged in the use and application of this important element. A desire to enforce more judicious and stringent regulations, to remunerate talent, and to employ only those whose good conduct and superior knowledge entitle them to confidence, is the only sure guarantee of public safety and the prosperity of the employer.

"Lastly, *The remedies applicable for the prevention of accidents arising from explosions.*

"Having noticed in the foregoing remarks most of the causes incident to boiler explosions, it now only remains to draw such inferences as will point out the circumstances which it is desirable to cultivate, and others which it is desirable to avoid. These circumstances I have endeavored to class in such a way as to bring the subject prominently forward, and to point out under each head, first, the causes which lead to accident; and, secondly, the means necessary to be observed in avoiding it. In a general summary, it may not be inexpedient briefly to recapitulate these statements, in order to impress more forcibly upon the mind of those concerned the necessity for care and consideration in the use of one of the most powerful agents ever placed at our disposal.

"One of the most scientific nations of Europe places the greatest confidence, as a means of safety, on the use of a fusible metal plate over the furnace. These plates are alloys of tin and lead, with a small portion of bismuth, in such proportions as will ensure fusion at a temperature something below that of molten lead. In France the greatest importance is attached to these alloys, and, in order to ensure certainty as to the definite proportions, the plates are prepared at the royal mint, where they may be purchased duly prepared for use In this country these alloys are not generally in use, but in this respect I think we are wrong, as boiler explosions are not so frequent in France as

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in this country, and high-pressure steam, from its superior economy, is more extensively used in France than in England. In my own practice I invariably insert a lead rivet, one inch in diameter, immediately over the fireplace, and as common lead melts at 620°, I have invariably found these metallic plugs a great security in the event of a scarcity of water in the boiler. I am persuaded many dangerous explosions may be avoided by the use of this simple and effective precaution; and as pure lead melts at 610°, we may infer from this circumstance that notice will be given and relief obtained before the internal pressure of the steam exceeds that of the resisting powers of the heated plates. As this simple precaution is so easily accomplished, I would advise its general adoption. It can do no harm to the boiler, and may be the means of averting explosions and the destruction of many valuable lives.

"The fusible metal plates, as used in France, are generally covered by a perforated metallic disc, which protects the alloy of which the plate is composed, and allows it to ooze through as soon as the steam has attained the temperature necessary to insure the fusion of the plate. The nature of the alloy is, however, somewhat curious, as the different equivalents have different degrees of fluidity, and the portion which is the first to melt is found out by the pressure of the steam causing the adhesion of the less fusible parts, but in a most imperfect state, and incapable of resisting the internal force of the steam. The result of these compounds is the fusion of one portion of the alloy and the fracture of the other, which is generally burst by pressure.

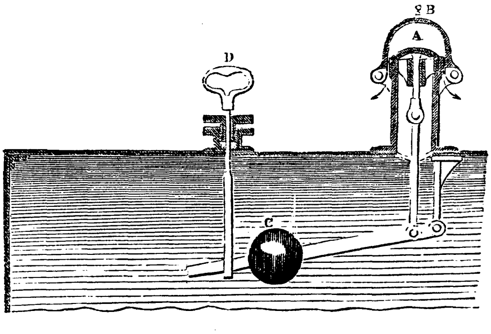
"This latter description of fusible plates is different from the lead plug over the fire, which is fused at 600° by the heat of the furnace, and the other, by the temperature of the steam, when raised to the fusible point of the alloy, which varies from 280° to 350°.

"Another method is the bursting plate, fixed in a frame and attached to some convenient part of the upper side of the boiler; this plate is to be of such thickness and of such ductility as to cause rupture whenever the pressure exceeds that of the weight on the safety valve. There can be no doubt that such an apparatus, if made with a sufficiently large opening, would relieve the boiler; but the objections to this and several other devices are the frequent bursting of those plates, and the effect every change of pressure has upon the material in reducing its powers of resistance, and thus increasing uncertainty as to the amount of pressure in the boiler, as well as the constant renewal of the plates.

"It has already been noticed that one of the most important securities against explosions is a duly proportioned boiler, well constructed; and to this must be added ample means for the escape of the steam on every occasion when the usual channels have been suddenly stopped. The only legitimate outlets under these circumstances appear to me to be the safety-valves, which, connected with this inquiry, are indispensable to security. Every boiler should, therefore, have two safety-valves, of sufficient capacity to carry off the quantity of steam generated by the boiler. One of these valves should be of the common construction, and the other beyond the reach of the engineer or any other person.

"*Fig.* 153 is a sketch of a lock-up safety-valve, as constructed by Mr. Fairbairn. A is the valve. B is a shell of thin brass, opening on an hinge and secured by a padlock; it is of such a diameter as to allow the waste steam to escape in the direction of the arrows. C is the weight, which may be fixed at any part of the lever to give the desired amount of pressure, but which cannot be fixed or altered unless the boiler is opened to allow a man to get inside. D is a handle, having a long slot, by which the valve may be relieved or tried at any time, to obviate the liability of its corroding or being jammed; the engineer cannot, however, put any additional weight upon the valve by this handle.'

153



"Whilst tracing the causes of explosions from a deficiency of water in the boiler, I have recommended as the usual precautions, good pumps, self-acting feeders, water cocks, glass gauges, floats, alarms, and other indicators which mark the changes and variations in the height of the water. To these may be added the steam whistle, but chiefly the constant inspection of a careful, sober, and judicious engineer. Above all other means however ingeniously devised, this is the most essential to security, for on that official depends, not only the security of the property under his charge, but also the interests of his family, and the lives of all those within the immediate influence of his operations. One of the most important considerations in this and every other department of management is cleanliness and the careful attention of a good sober engineer.

"Explosions produced from collapse have their origin in different causes to those arising from a deficiency of water, and the only remedy that can be applied is the vacuum valve and the cylindrical or spheroidal form of boiler.

"Defective construction is unquestionably one of the greatest sources of the frightful accidents which we are so frequently called upon to witness. No man should be allowed unlimited exercise of judgment on a question of such vital importance as the construction of a boiler, unless duly qualified by matured experience in the theoretical and practical knowledge of form, strength of materials, and other requirements requisite to insure the maximum of sound construction. It appears to me equally important that we should have the same proofs and acknowledged system of operations in the construction of boilers, as we have in the strength and proportions of ordnance. In both cases we have to deal with a powerful and dangerous element; and I have yet to learn why the same security should not be given to the general public as we find so liberally extended to an important branch of the public service. In the ordnance department at Woolwich (with which I have been more or less connected for some years) the utmost care and precision is observed in the manufacture of guns; and the proofs are so carefully made under the superintendence of competent officers, as to render every gun perfectly safe to the extent of 1000 to 1200 rounds of shot.

"Boilers and artillery are equally exposed to fracture, and it appears to me of little moment whether the one is burst by the discharge of gunpowder, or the other by the elastic force of steam.

"Taking into consideration all the circumstances connected with the bursting of boilers and the bursting of guns, and looking at the active competition which exists, and is likely to be extended, in manufactories, railway traffic, and steam navigation, rendering it every day more desirable to reduce the cost by an extended use of steam at a much higher pressure, it surely becomes a desideratum to secure the public safety by the introduction of some generally acknowledged system of construction that will bear the test of experience, and involve a maximum power of resistance. The most elaborate disquisitions have taken place, by the most distinguished men of all ages since the invention of gunpowder, to discover the strength and form of guns of every description. Surely boilers are equally if not more important, as the sacrifice of human life appears to me much greater in the one case than the other. It is therefore a subject of paramount importance to the public to know that the facts of scientific inquiry, and the knowledge of practical skill, have combined to give *undeniable security as well as confidence*, that boilers are properly constructed, and capable of bearing at least *six times* their working pressure.

"On the question of explosions arising from mismanagement and ignorance, we have little further to add; and it now only remains to state, that the subject of security from boiler explosions is of such importance as to call for more able exponents than myself. I have endeavored to trace the causes of these lamentable occurrences, and to draw such deductions therefrom as I trust may be useful in at least mitigating, if not almost entirely averting, the danger.

"I repeat the means of prevention and the precautions necessary to be observed in the construction and management of boilers.

"1st. To avoid explosions from internal pressure, cylindrical boilers of maximum forms and strength must be used, including all the necessary appendages of safety-valves, &c.

"2d. Explosions arising from deficiency of water may be prevented by the fusible alloys, bursting plates, good feed pumps, water gauges, alarms and other marks of indication; but above all, the experienced eye and careful attention of the engineer is the greatest security.

"3d. Explosions from collapse are generally produced from imperfect construction, which can only be remedied by adopting the cylindrical form of boiler, and a valve to prevent the formation of vacuum in the boiler.

"4th. Explosions from defective construction admit of only one simple remedy, and that is, the adoption of those forms which embody the maximum powers of resistance to internal pressure, and such as we have already recommended for general use.

"Lastly. Good and efficient management, a respectable and considerate engineer, and the introduction of such improvements, precautions, and securities as we have been able to recommend, will not only ensure confidence, but create a better system of management in all the requirements necessary to be observed for the prevention of steam boiler explosions. (*Fairbairn, in Lecture at Leeds.*)

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BOMBAZINE. A worsted stuff, sometimes mixed with silk.

BONES. (*Os*, Fr.; *Knochen*, Germ.) They form the frame work of animal bodies, commonly called the skeleton; upon which the soft parts are suspended, or in which they are enclosed. Bones are invested with a membrane styled the periosteum, which is composed of a dense tissue affording glue; whence it is convertible into jelly, by ebullition with water. Bones are not equally compact throughout their whole substance; the long ones have tubes in their centres lined with a kind of periosteum, of more importance to the life of the bones than even their external coat. The flat, as well as the short and thick bones, exhibit upon their surface an osseous mass of a dense nature, while their interior presents a cavity divided into small cellules by their bony partitions.

In reference to the composition of bones, we have to consider two principal constituents; the living portion or the osseous cartilage, and the inorganic or the earthy salts of the bones.

The osseous cartilage is obtained by suspending bones in a large vessel full of dilute muriatic acid, and leaving it in a cool place at about 50° Fahr. for example. The acid dissolves the earthy salts of the bones without perceptibly attacking the cartilage, which, at the end of a short time, becomes soft and translucid, retaining the shape of the bones; whenever the acid is saturated, before it has dissolved all the earthy salts it should be renewed. The cartilage is to be next suspended in cold water, which is to be frequently changed till it has removed all the acidity. By drying, the cartilage shrinks a little, and assumes a darker hue, but without losing its translucency. It becomes, at the same time, hard and susceptible of breaking when bent, but it possesses great strength.

This cartilage is composed entirely of a tissue passing into gelatine. By boiling with water, it is very readily convertible into a glue, which passes clear and colorless through the filter, leaving only a small portion of fibrous matter insoluble by further boiling. This matter is produced by the vessels which penetrate the cartilage, and carry nourishment to the bone. We may observe all these phenomena in a very instructive manner, by macerating a bone in dilute muriatic acid, till it has lost about the half of its salts; then washing it with cold water, next pouring boiling water upon it, leaving the whole in repose for 24 hours, at a temperature a few degrees below 212° Fahr.

The cartilage, which has been stripped of its earthy salts, dissolves, but the small vessels which issue from the undecomposed portion of the bone remain under the form of white plumes, if the water has received no movement capable of crushing or breaking them. We may then easily recognise them with a lens, but the slightest touch tears them, and makes them fall to the bottom of the vessel in the form of a precipitate; if we digest bones with strong hot muriatic acid so as to accelerate their decomposition, a portion of the cartilage dissolves in the acid with a manifest disengagement of carbonic acid gas, which breaks the interior mass, and causes the half-softened bone to begin to split into fibrous plates, separable in the direction of their length. According to Marx, these plates, when sufficiently thin, possess, like scales of mica, the property of polarizing light, a phenomenon which becomes more beautiful still when we soak them with the essential oil of the bark of the Laurus Cassia. The osseous cartilage is formed before the earthy part. The long bones are then solid, and they become hollow only in proportion as the earthy salts appear. In the new-born infant, a large portion of the bones is but partially filled with these salts, their deposition in cartilage takes place under certain invariable *points of ossification*, and begins at a certain period after conception, so that we may calculate the age of the fœtus according to the progress which ossification has made.

The earthy parts of bones are composed principally of the phosphate and carbonate of lime in various proportions, variable in different animals, and mixed with small quantities, equally variable, of phosphate of magnesia and fluate of lime. The easiest means of procuring the earthy salts of bones consists in burning them to whiteness, but the earthy residuum procured in this manner, contains substances which did not exist beforehand in the bones, and which did not form a part of their earthy salts; as, for example, sulphate of soda, produced at the expense of the sulphur of the bones and the alkaline carbonate, proceeding from the cartilage with which it was combined. On the other hand, the greater part of the lime has lost its carbonic acid. As the sulphuric acid is the product of combustion, it is obvious that an acidulous solution of a fresh bone can afford no precipitate with muriate of barytes. The phosphate of lime contained in the bone-salts is a subphosphate, consisting, according to Berzelius, of three prime equivalents of the acid, and eight of the base; or of 2,677 parts of the former, and 2,818 of the latter. It is always obtained when we precipitate the phosphate of lime by an excess of ammonia. When calcined bones are distilled in a retort with their own weight of sulphuric acid, a little fluoric acid is disengaged, and it acts on the surface of the glass. The following analyses of the bones of men and horned cattle, are given by Berzelius. They were dried after being stripped of their fat and periosteum till they lost no more weight.

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	Human bone.	Ox bone.
Cartilage completely soluble in water	32·17	33·3
Vessels	1·13	
Subphosphate with a little fluate of lime	53·04	57·35
Carbonate of lime	11·3	3·85
Phosphate of magnesia	1·16	2·05
Soda with very little muriate of soda	1·20	3·45
	100·00	100·00

The most essential difference in the composition of these bones is that those of man contain three times as much carbonate of lime as those of the ox; and that the latter are richer in phosphate of lime and magnesia in the same proportion. Fernandez de Barros has established a comparison between the phosphate and carbonate of lime in the bones of different animals. He found in 100 parts of earthy salt of the bones of the following animals:—

	Phosphate of lime	Carb. lime.
Lion	95·0	2·5
Sheep	80·0	19·3
Hen	83·9	10·4
Frog	95·2	2·4
Fish	91·9	5·3

The bones of fish are divided into those which contain earthy salts and those which have none, called cartilaginous fishes. The enamel of the teeth is composed as follows:—

	Human enamel.	Ox enamel.
Phosphate of lime with fluate of lime	88·5	85·0
Carbonate of lime	8·0	7·1
Phosphate of magnesia	1·5	3·0
Soda	0·0	1·4
Brown membranes attached to the tooth, alkali, water	2·0	3·5
	100·0	100·0

In the arts, the bones are employed by turners, cutlers, manufacturers of animal charcoal, and, when calcined, by assayers for making cupels. In agriculture, they are employed as a manure, for which purpose they should be ground in a mill, and the powder sowed along with the seeds in a drill. It is supposed, in many cases, to increase the crop in weight of grain and straw together, by from 40 to 50 per cent. In France, soup is extensively made by dissolving bones in a steam-heat of two or three days' continuance. The shavings of hartshorn, which is a species of bone, afford an elegant jelly: the shavings of calves' bones may be used in their stead.

Living bones acquire a red tinge when the animals receive madder with their food; but they lose it when the madder is discontinued for some time.

The following analysis of the middle part of the thigh-bone of a man of 30 years of age by Marchand, merits confidence:—

1.	Cartilage insoluble in muriatic acid	27·23
2.	Do. soluble in do.	5·02
3.	Blood-vessels and nerves	1·01
4.	Subphosphate of lime	52·26
5.	Fluoride of calcium	1·00
6.	Carbonate of lime	10·21
7.	Phosphate of magnesia	1·05
8.	Soda	0·92
9.	Chlorsodium	0.25
10.	Oxides of iron and manganese, and loss	1.05
		100·00

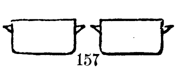
The human bones contain much more carbonate of lime than those of oxen; which are, however, richer in phosphate of lime and magnesia. The proportion of cartilaginous matter in bones is not uniform, but varies in the same species of animal with age, sex, and pasture. The quantity of bones imported in 1850 amounted to 27,198 tons, and in 1851 to 31,956 tons.

BONE BLACK (*Noir d'os*, Fr.; *Knochenschwartz*, Germ.), or *Animal charcoal*, as it is less correctly called, is the black carbonaceous substance into which bones are converted by calcination in close vessels. This kind of charcaol has two principal applications: to deprive various solutions, particularly sirups, of their coloring matters, and to furnish a black pigment. The latter subject will be treated of under Ivory Black.

The discovery of the antiputrescent and decoloring properties of charcoal in general, is due to Lowitz, of Petersburg; but their modifications have occupied the attention of many chemists since his time. Kels published, in 1798, some essays on the discoloring of indigo, saffron, madder, sirup, &c. by means of charcoal, but he committed a mistake in supposing bone black to have less power than the charcoal of wood. The first useful application of charcoal to the purification of raw colonial sugar was made by M. Guillon, who brought into the French markets considerable quantities of fine sirups, which he discolored by ground wood charcoal, and sold them to great advantage, as much superior to the cassonades of that time. In 1811, M. Figuier, an apothecary at Montpellier, published a note about animal charcoal, showing that it blanched vinegars and wines with much more energy than vegetable charcoal; and, lastly, in 1812, M. Derosnes proposed to employ animal charcoal in the purification of sirups and sugar refining. The quantities of bone black left in the retorts employed by MM. Payen, for producing crude carbonate of ammonia, furnished abundant materials for making the most satisfactory experiments, and enabled these gentlemen soon to obtain ten per cent. more of refined sugar from the raw article than had been formerly extracted, and to improve, at the same time, the characters of the lumps, bastards, treacle, &c.

The calcination of bones is effected by two different systems of apparatus; by heating them in a retort similar to that in which coal is decomposed in the gas works, or in small pots piled up in a kiln. For the description of the former, see Gas-Light. On the second plan, the bones, broken into pieces, are put into small cast-iron pots of the form shown in *fig.* 154, about three eighths of an inch thick, two of which are dexterously placed with their mouths in contact, and then luted together with loam. The lip of the upper pot is made to slip inside of the under one. These double vessels, containing together about fifty pounds of bones, are arranged alongside, and over each other, in an oven, like a potter's kiln, till it be filled. The oven or kiln may be either oblong or upright. The latter is represented in *figs.* 155, 156, 157. A is the fireplace or grate for the fuel; C C are the openings in the dome of the furnace through which the flame flows; the divisions of these orifices are shown in *fig.* 157. B is the wall of brick-work. D the space in which the pots are distributed. E is the door by which the workman carries in the pots, which is afterwards built up with fire-bricks, and plastered over with loam. This door is seen in *fig.* 155. F F are the lateral flues for conveying the disengaged gases into the air.

154



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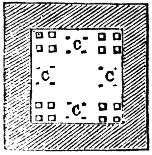

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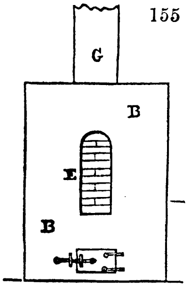

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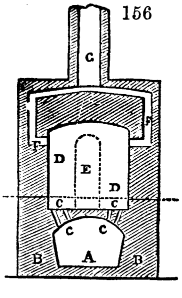

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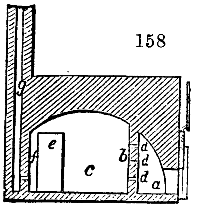

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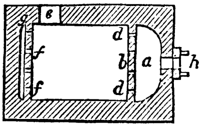

Fig. 158 is a longitudinal section, and *fig.* 159, a ground plan of a horizontal kiln for calcining bones. *a* is the fire-chamber, lying upon a level with the sole of the kiln; it is separated by a pillar *b*, from the calcining hearth *c*. In the pillar or wall, several rows of holes *d*, are left at different heights; *e* is the entrance door; *f*, the outlet vents for the gases, vapors, and smoke, into the chimney *g*; *h*, a sliding damper-plate for regulating the admission of the air into the fire in the space *a*.

By this arrangement the offensive emanations are partly consumed, and partly carried off with the smoke. To destroy the smell completely, the smoke should be made to pass through a second small furnace.

The number of pots that may be put into a kiln of this kind depends, of course, upon its dimensions; but, in general, from 100 to 150 are piled up over each other, in columns, at once; the greatest heat being nearest the roof of the kiln; which resembles, in many respects, that used for baking pottery ware.

In both kilns the interior walls are built of fire-bricks. In the oblong one, the fiercest heat is near the vaulted roof; in the upright one, near the sole; and the pots, containing the larger lumps of bones, should be placed accordingly near the top of the former, and the bottom of the latter. Such a kiln may receive about seventy double pots, containing in the whole thirty-five cwt. of bones.

After the earth is filled with the pots, and the entrance door is shut, the fire is applied at first moderately, but afterwards it must be raised and maintained, at a brisk heat, for eight or ten hours. The door of the ash-pit and the damper may now be nearly closed, to moderate the draught, and to keep up a steady ignition for six or eight hours longer, without additional firing; after which the doors must be all opened to cool the furnace. When this is done, the brick-work of the entrance door must be taken down, the kiln must be emptied, and immediately filled again with a set of pots previously filled with bones, and luted together; the pots which have been ignited may, in the course of a short time, be opened, and the contents put into the magazine. But in operating with the large decomposing cylinder retort, the bones being raked out hot, must be instantly tossed into a receiver, which can be covered in air-tight till they are cool.

The bones lose upon the average about one half of their weight in the calcination. In reference to the quality of the black, experience has shown that it is so much more powerful as a discoloring agent, as the bones from which it was made have been freer from adhering fatty, fleshy, and tendinous matters.

The charcoal is ground in a mill, either to a fine powder and sifted, or into a coarse granular state, like gunpowder, for the preparation of which two sieves are required, one with moderately fine meshes, to allow the small dust to pass through, and one with large meshes, to separate the proper-sized grains from the coarser lumps. Either a corn-mill, an edgestone mill, or a steel cylinder mill, may be employed for grinding bone-black, and it is generally damped in the operation to keep down the fine dust.

Bone-black, as found in commerce, is very variable in its discoloring power, which arises from its having been exposed either to too great a heat which has glazed its carbon, or too low a heat which has left its albumen imperfectly decomposed. A steady ignition of due continuance is the proper decomposing temperature. Its composition is generally as follows:—

Phosphate of lime, with carbonate of lime, and a little sulphuret of iron, or oxyde of iron, 88 parts; iron in the state of a silicated carburet, 2 parts; charcoal containing about one fifteenth of azote, 10 parts. None of the substances present, except the charcoal, possesses separately any discoloring power.

The quality may be tested by a solution of brown sugar, or, molasses, or of indigo in sulphuric acid. The last is generally preferred by the French chemists, who have occupied themselves most with this subject, and it contains usually one thousandth part of its weight of this dye-drug of the best quality. Other animal substances yield a charcoal, possessed of very considerable discoloring properties. The following table by M. Bussy exhibits an interesting comparison of almost every kind of charcoal in this point of view.

Table of the discoloring powers of different charcoals.

Species of Charcoal.	Weight.	Indigo test consumed.	Molasses test consumed.	Blanching by indigo.	Power by molasses.
	Gramme.	Litres.			
Blood calcined with potash	1	1·60	0·18	50	20
Ditto with chalk - - -	1	0·57	0·10	18	11
Ditto with phosphate lime	1	0·38	0·09	12	10
Gelatine ditto with potash	1	1·15	0·14	36	15·5
Albumen ditto ditto - -	1	1·08	0·14	34	15·5
Starch ditto ditto - - -	1	0·34	0·08	10·6	8·8
Charcoal from acet. potash	1	0·18	0·04	5·6	4·4
Ditto from carb. soda by phosphorus - - - -	1	0·38	0·08	12	8·8
Calcined lamp black - -	1	0·128	0·03	4	3·3
Ditto ditto potash - - -	1	0·55	0·09	15·2	10·6
Bone black treated with mur. acid and potash -	1	1·45	0·18	45	20
Bone black ditto with mur. acid - - - - -	1	0·06	0·015	1·87	1·6
Oil calcined with phosph. of lime - - - - -	1	0·064	0·017	2	1·9
Crude bone black - - -	1	0·032	0·009	1	1

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With regard to the mode of operation of bone black on colored liquids, M. Payen showed in his prize essay, 1. That the decoloring power of charcoal depends in general upon its state of division; 2. That in the various charcoals, the carbonaceous matter acts only upon the coloring matters, combining with and precipitating them; 3. That in the application of charcoal to the refining of sugar, it acts also upon the gluten, for it singularly promotes crystallization; 4. That according to the above principles, the decoloring action of charcoals may be so modified, as to make the most inert become the most active; 5. That the distinction between animal and vegetable charcoals is improper, and that we may substitute for it that of dull and brilliant charcoals; 6. That of the substances present in charcoal besides carbon, and particularly animal charcoal, those which favor the decoloring action, have an influence relative only to the carbon; they serve as auxiliaries to it, by insulating its particles, and presenting them more freely to the action of the coloring matter; 7. That animal charcoal, besides its decoloring power, has the valuable property of taking lime in solution from water and sirup; 8. That neither vegetable, nor other charcoals, besides the animal, have this power of abstracting lime; 9. That by the aid of the decolorimeter, or graduated tube charged with test solution of indigo or molasses, it is easy to appreciate exactly the decoloring properties of all kinds of charcoal.

Different varieties of lignite (fossilized wood) or even pit coal, when well carbonized in close vessels, afford a decoloring charcoal of considerable value. By reducing 100 parts of clay into a thin paste with water, kneading into it 20 parts of tar, and 500 of finely-ground pit coal, drying the mixed mass, and calcining it out of contact of air, a charcoally matter may be obtained not much inferior to bone-black in whitening sirups.

The restoration of animal charcoal from burnt bones, for the purpose of sugar refining, has been long practised in France. Mr. W. Parker has lately made the following process the subject of a patent. The charcoal, when taken from the vessel in which it has been employed for the purposes of clarifying the sugar, is to be thoroughly washed with the purest water that can be obtained, in order to remove all the saccharine matter adhering to it. When the washing process has been completed, the charcoal is laid out to dry, either in the open air or in a suitable stove, and when perfectly free from moisture, it is to be separated into small pieces and sifted through a sieve, the wires or meshes of which are placed at distances of about two and a half in every inch. This sifting will not only divide the charcoal into small pieces, but will cause any bits of wood or other improper matters to be separated from it.

The charcoal, thus prepared, is then to be packed lightly in cylindrical vessels called crucibles, with some small quantity of bones, oil, or other animal matter mixed with it. The crucibles are then to be closed by covers, and luted at the joints, leaving no other opening but one small hole in the centre of the cover, through which any gas, generated within the vessel when placed in the oven or furnace, may be allowed to escape.

The crucibles are now to be ranged round the oven, and placed, one upon another, in vertical positions; and when the oven is properly heated, gas will be generated within each crucible, and issue out from the central hole. The gas thus emitted, being of an inflammable quality, will take fire, and assist in heating the crucibles; and the operation being carried on until the crucibles become of a red heat, the oven is then to be closed, and allowed to cool; after which the crucibles are to be removed, when the charcoal will be found to have become perfectly renovated, and fit for use as before.

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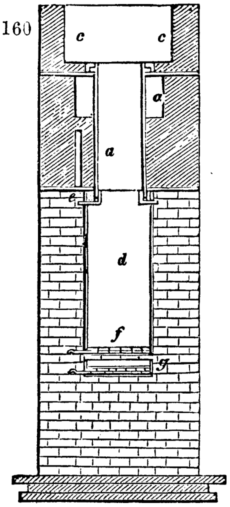

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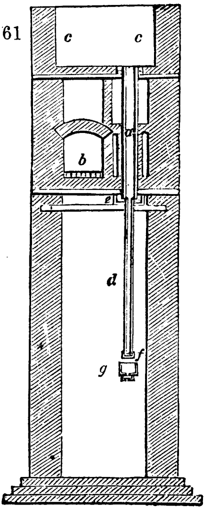


Bone Black, or animal charcoal *restored*. A process for this purpose was made the subject of a patent by Messrs. Bancroft and MacInnes of Liverpool, which consists in washing the granular charcoal, or digesting it when finely ground, with a weak solution of potash or soda, of specific gravity 1·06. The bone black which has been used in sugar refining may thus be restored, but it should be first cleared from all the soluble filth by means of water

Mr. F. Parker's method, patented in June, 1839, for effecting a like purpose, is by a fresh calcination as follows:—

Fig. 160 represents a front section of the furnace and retort; and *fig.* 161 is a transverse vertical section of the same. *a* is a retort, surrounded by the flues of the furnace *b* ; *c* is a hopper or chamber, to which a constant fresh supply of the black is furnished, as the preceding portion has been withdrawn, from the lower part of *a*. *d* is the cooling vessel, which is connected to the lower part of the retort *a* by a sand joint *e*. The cooler *d* is made of thin sheet iron, and is large; its bottom is closed with a slide plate *f*. The black after passing slowly through the retort *a* into the vessel *d*, gets so much cooled by the time it reaches *f*, that a portion of it may be safely withdrawn, so as to allow more to fall progressively down; *g* is the charcoal meter, with a slide door.

BOOKBINDING, is the art of sewing together the sheets of a book, and securing them with a back and side boards.

Bookbinding, according to the present mode, is performed in the following manner:—The sheets are first folded into a certain number of leaves, according to the form in which the book is to appear; viz., two leaves for folios, four for quartos, eight for octavos, twelve for duodecimos, &c. This is done with a slip of ivory or boxwood, called a folding-stick; and in the arrangement of the sheets the workmen are directed by the catch-words and signatures at the bottom of the pages. When the leaves are thus folded and arranged in proper order, they are usually beaten upon a stone with a heavy hammer, to make them solid and smooth, and are then condensed in a press. After this preparation they are sewed in a sewing press, upon cords or packthreads called bands, which are kept at a proper distance from each other, by drawing a thread through the middle of each sheet, and turning it round each band, beginning with the first and proceeding to the last. The number of bands is generally six for folios, and five for quartos, or any smaller size. The backs are now glued, and the ends of the bands are opened, and scraped with a knife, that they may be more conveniently fixed to the pasteboard sides; after which the back is turned with a hammer, the book being fixed in a press between boards, called backing boards, in order to make a groove for admitting the pasteboard sides. When these sides are applied, holes are made in them for drawing the bands through, the superfluous ends are cut off, and the parts are hammered smooth. The book is next pressed for cutting; which is done by a particular machine called the plough, to which is attached a knife. See the figures and descriptions *infra.* It is then put into a press called the cutting press, betwixt two boards, one of which lies even with the press, for the knife to run upon; and the other above for the knife to cut against. After this the pasteboards are cut square with a pair of iron shears; and last of all, the colors are sprinkled on the edges of the leaves, with a brush made of hog's bristles; the brush being held in the one hand, and the hair moved with the other.

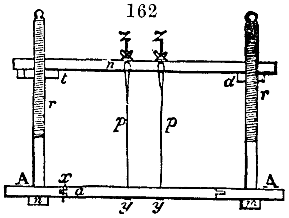
A patent was obtained in 1799 by Messrs. John and Joseph Williams, stationers in London, for an improved method of binding books of every description. The improvement consists of a back, in any curved form, turned a little at the edges, and made of iron, steel, copper, brass, tin, or of ivory, bone, wood, vellum, or, in short, any material of sufficient firmness. This back is put on the book before it is bound, so as just to cover without pressing the edges; and the advantage of it is that it prevents the book, when opened, from spreading on either side, and causes it to rise in any part to nearly a level surface. In this method of binding the sheets are prepared in the usual manner, then sewed on vellum slips, glued, cut, clothed, and boarded, or half boarded; the firm back is then fastened to the sides by vellum drawn through holes, or secured by enclosing it in vellum or ferret wrappers, or other materials pasted down upon the boards, or drawn through them.

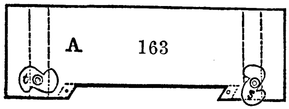
A patent was likewise obtained in 1800 by Mr. Ebenezer Palmer, a London stationer, for an improved way of binding books, particularly merchants' account-books. This improvement has been described as follows:—let several small bars of metal be provided, about the thickness of a shilling or more, according to the size and thickness of the book; the length of each bar being from half an inch to several inches, in proportion to the strength required in the back of the book. At each end of every bar let a pivot be made of different lengths, to correspond to the thickness of two links which they are to receive. Each link must be made in an oval form, and contain two holes proportioned to the size of the pivots, these links to be the same metal as the hinge, and each of them nearly equal in length to the width of two bars. The links are then to be riveted on the pivots, each pivot receiving two of them, and thus holding the hinge together, on the principle of a link-chain or hinge. There must be two holes or more of different sizes, as may be required, on each bar of the hinge or chain; by means of these holes each section of the book is strongly fastened to the hinge which operates with the back of the book, when bound, in such a manner as to make the different sections parallel with each other, and thus admit writing without inconvenience on the ruled lines, close to the back.

The leather used in covering books is prepared and applied as follows: being first moistened in water, it is cut to the size of the book, and the thickness of the edge is paired off on a marble stone. It is next smeared over with paste made of wheat flour, stretched over the pasteboard on the outside, and doubled over the edges within. The book is then corded, that is, bound firmly betwixt two boards, to make the cover stick strongly to the pasteboard and the back; on the exact performance of which the neatness of the book in a great measure depends. The back is then warmed at the fire to soften the glue, and the leather is rubbed down with a bodkin or folding stick, to set and fix it close to the back of the book. It is now set to dry, and when dry, the boards are removed; the book is then washed or sprinkled over with a little paste and water, the edges and squares blacked with ink, and then sprinkled fine with a brush, by striking it against the hand or a stick; or with large spots, by being mixed with solution of green vitriol, which is called marbling. Two blank leaves are then pasted down to the cover, and the leaves, when dry, are burnished in the press, and the cover rolled on the edges. The cover is now glazed twice with the white of an egg, filleted, and, last of all, polished, by passing a hot iron over the glazed color.

The employment in bookbinding of a rolling press for smoothing and condensing the leaves, instead of the hammering which books have usually received, is an improvement introduced several years ago into the trade by Mr. W. Burn. His press consists of two iron cylinders about a foot in diameter, adjustable in the usual way, by means of a screw, and put in motion by the power of one man or of two, if need be, applied to one or two winch-handles. In front of the press sits a boy who gathers the sheets into packets, by placing two, three, or four, upon a piece of tin plate of the same size, and covering them with another piece of tin plate, and thus proceeding by alternating tin plates and bundles of sheets till a sufficient quantity have been put together, which will depend on the stiffness and thickness of the paper. The packet is then passed between the rollers and received by the man who turns the winch, and who has time to lay the sheets on one side, and to hand over the tin plates by the time that the boy has prepared a second packet. A minion Bible may be passed through the press in one minute, whereas the time necessary to beat it would be twenty minutes. It is not, however, merely a saving of time that is gained by the use of the rolling-press; the paper is made smoother than it would have been by beating, and the compression is so much greater, that a rolled book will be reduced to about five sixths of the thickness of the same book if beaten. A shelf, therefore, that will hold fifty books bound in the usual way would hold nearly sixty of those bound in this manner, a circumstance of no small importance, when it is considered how large a space even a moderate library occupies, and that book-cases are an expensive article of furniture. The rolling-press is now substituted for the hammer by several considerable bookbinders.

162





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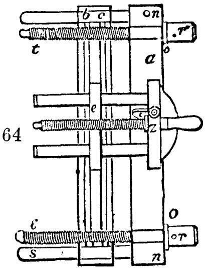


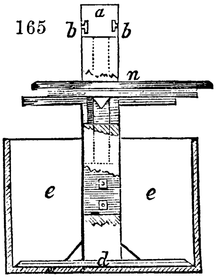
Fig. 162 represents the sewing-press, as it stands upon the table, before which the bookbinder sits. *Fig.* 163 is a ground plan, without the parts *a* and *n* in the former figure. A is the base-board, supported upon the cross bars *m n*, marked with dotted lines in *fig.* 163. Upon the screw rods *r r*, *fig.* 162, the nuts *t d* serve to fix the flat upper bar *n*, at any desired distance from the base. That bar has a slit along its middle, through which the hooks below *z z* pass down for receiving the ends of the sewing cords *p p*, fixed at *y y*, and stretched by the thumb-screws *z z*. The bar *y y* is let into an oblong space cut out of the front edge of the base-board, and fixed there by a moveable pin *a*, and a fixed pin at its other end, round which it turns.

Fig. 164 is the bookbinder's cutting-press, which is set upright upon a sort of chest for the reception of the paper parings; and consists of three sides, being open above and to the left hand of the workman. The pressbar, or beam *a*, has two holes *n n* upon its under surface, for securing it to two pegs standing on the top of the chest. The screw rods *t t* pass through two tapped holes in the bar, marked with *b c* at its upper end; their heads *r r* being held by the shoulders *o o*. The heads are pierced with holes into which lever pins are thrust for screwing the rods hard up. The heavy beam *a* remains immoveable, while the parallel bar with the book is brought home towards it by the two screws. The two rulers *s s* serve as guides to preserve the motions truly parallel; and the two parallel lath bars *b c* guide between them the end bar *e*, of the plough, whose knife is shown at *i*, with its clamping screw *z*.

Mr. Oldham, printing engineer of the Bank of England, distinguished for mechanical ingenuity, has contrived a convenient machine for cutting the edges of books, banknotes, &c., either truly square or polygonal, with mathematical precision. *Fig.* 165, represents an end elevation of the machine. *Fig.* 166, a side view of the same, the letters of reference indicating the same parts of the machine in each of the figures.

a, is the top cross bar with rectangular grooves *b b*; *c c*, are side posts; *d d*, cross feet to the same, with strengthening brackets; *e e*, a square box, in which the press stands for holding waste cuttings. *Fig.* 167, is a cross section of the upright posts, *c c*, taken horizontally. There are rectangular grooves in the upright posts, for the projecting ends of the cast iron cross bracket *f*, to slide up and down in. In the middle of the under-side of this piece *f*, there is a boss, within which is a round recess, to receive the top of the screw *g*, which works in the cast iron cross piece *h*, similarly made with the former, but bolted firmly to the posts *c c*. Upon the screw *g*, there is a circular handle or ring *i*, for partially turning the screw, and immediately over it cross holes for tightening the press by means of a lever bar. Upon the cross piece *f*, is bolted the board *j*, and upon each end of this board is made fast the rabbeted pieces *k k*, for another board *l*, to slide in.

165



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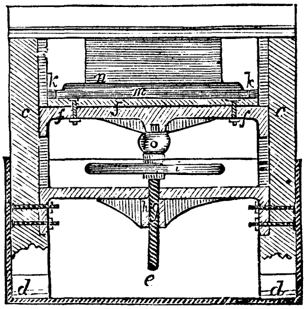

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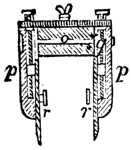

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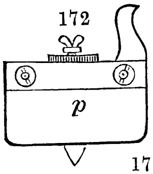

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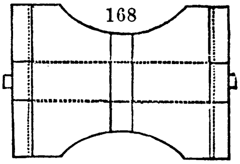

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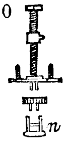

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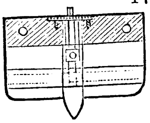

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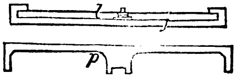

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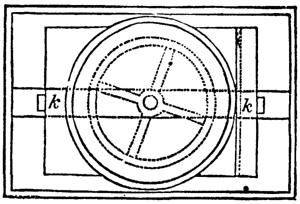

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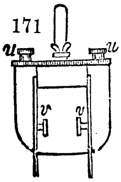

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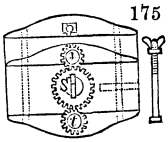

Across the middle of this board, and parallel to the pieces *k k*, the tongue piece *m* is made fast, which fits into a groove in the bottom of board *l*. A horizontal representation of this is seen at *fig.* 168, and immediately under this view is also seen an end view of *l* and *f*, connected together, and a side view of *f* by itself. In the middle of the board *l*, is a pin for a circular board *n*, to turn upon, and upon this letter board is placed the "material to be cut," with a saving piece between it, and the circular piece which is to be divided upon its edge into any number of parts required, with a stationary index on the board *l*, to point to each.

It will now be understood that the "material to be cut," may be turned round upon the centre pin of the board *n*, and also that both it and the board can be shifted backward and forward under the top cross piece *a*, and between the side slide slips *k k*, the surfaces of which should also be divided into inches and tenths.

The plough, *fig.* 169, shown in several positions, is made to receive two knives or cutters as the "material to be cut" may require, and which are situated in the plough as I now describe. The plough is composed of three principal parts, namely, the top, and its two sides. The top *o*, is made the breadth of the cross piece *a*, and with a handle made fast thereon. The sides *p p*, are bolted thereto, with bolts and nuts through corresponding holes in the top and sides. The figures below give inside views, and cross sections of the details of the manner in which the cutters and adjustments are mounted. A groove is cut down each cheek or side, in which are placed screws that are held at top and bottom from moving up and down, but by turning they cause the nuts upon them to do so; they are shown at *q q*. These nuts have each a pin projecting inwards, that go into plain holes made in the top ends of cutters *r r*. The 169th and following figs. are $\frac{1}{4}$ in scale.

The cutters, and the work for causing them to go up and down, are sunk into the cheeks, so as to be quite level with their inner surfaces. *Fig.* 170 shows one of those screws apart, how fixed, and with moveable nut and projecting pin. The top of each screw terminates with a round split down, and above it a pinion wheel and boss thereon, also similarly split. This pinion fits upon the split pin. Above, there is a cross section of a hollow coupling cap with steel tongue across, that fits into both the cuts of the screw pin and pinion boss, so that when lowered upon each other, they must all turn together. In the middle and on the top of the upper piece *o*, the larger wheel *s*, runs loose upon its centre, and works into the two pinion-wheels *t t*. The wheel *s* has a fly-nut with wings mounted upon it.

It will now be seen, when the plough is in its place as at *fig.* 171, that if it be pushed to and fro by the right hand, and the nut occasionally turned by the left, the knives or cutters will be protruded downwards at the same time, and these either will or will not advance as the coupling caps *u u* are on or off The ribs *v v*, run in the grooves *b b*, *fig.* 165, and keep the cutters to their duty, working steadily. The top cross bar *a*, is the exact breadth of a bank-note, by which means both knives are made to cut at the same time. The paper is cut uniformly to one length, and accurately square.

By the use of this machine, the air-pump paper-wetting apparatus, and appendant press, the paper of 45,000 notes is fully prepared in one hour and a half by one person, and may then be printed. It is not so much injured by this process as by the ordinary method of clipping by hand, soaking it, &c., which more or less opens and weakens the fabric, especially of bank-note paper.

One of the greatest improvements ever made in the art of bookbinding is, apparently, that for which Mr. William Hancock has very recently obtained a patent. After folding the sheets in double leaves, he places them vertically, with the edges forming the back of the book downwards in a concave mould, of such rounded or semi-cylindrical shape as the back of the book is intended to have. The mould for this purpose consists of two parallel upright boards, set apart upon a cradle frame, each having a portion or portions cut out vertically, somewhat deeper than the breadth of the book, but of a width nearly equal to its thickness before it is pressed. One of these upright boards may be slidden nearer to or farther from its fellow, by means of a guide bar, attached to the sole of the cradle. Thus the distance between the concave bed of the two vertical slots in which the book rests, may be varied according to the length of the leaves. In all cases about one fourth of the length of the book at each end projects beyond the board, so that one half rests between the two boards. Two or three packthreads are now bound round the leaves thus arranged, from top to bottom of the page in different lines, in order to preserve the form given to the back of the mould in which it lay. The book is next subjected to the action of the press. The back, which is left projecting *very slightly* in front, is then smeared carefully by the fingers with a solution of caoutchouc, whereby each paper-edge receives a small portion of the cement. In a few hours it is sufficiently dry to take another coat of a somewhat stronger caoutchouc solution. In 48 hours, 4 applications of the caoutchouc may be made and dried. The back and the adjoining part of the sides are next covered with the usual band or fillet of cloth, glued on with caoutchouc; after which the book is ready to have the boards attached, and to be covered with leather or parchment as may be desired.

We thus see that Mr. Hancock dispenses entirely with the operations of stitching, sewing, sawing-in, hammering the back, or the use of paste and glue. Instead of leaves attached by thread stitches at 2 or 3 points, we have them agglutinated securely along their whole length. Books bound in this way open so perfectly flat upon a table without strain or resilience, that they are equally comfortable to the student, the musician, and the merchant. The caoutchouc cement moreover being repulsive to insects, and not affected by humidity, gives this mode of binding a great superiority over the old method with paste or glue, which attracted the ravages of the moth, and in damp situations allowed the book to fall to pieces. For engravings, atlasses, and ledgers, this binding is admirably adapted, because it allows the pages to be displayed most freely without the risk of dislocating the volume; but for security, 3 or 4 stitches should be made. The leaves of music books bound with caoutchouc, when turned over lie flat at their whole extent, as if in loose sheets, and do not torment the musician like the leaves of the ordinary books, which are so ready to spring back again. Manuscripts and collections of letters which happen to have little or no margin left at the back for stitching them by, may be bound by Mr. Hancock's plan without the least encroachment upon the writing. The thickest ledgers thus bound, open as easily as paper in quire, and may be written on up to the innermost margin of the book without the least inconvenience.

Bookbinding, *Mechanical.*—An ingenious invention, for which Mr. Thomas Richards of Liverpool, bookbinder, obtained a patent in April 1842. He employs, first a mechanism to sew, weave, or bind a number of sheets together to form a book, instead of stitching them by hand; 2dly, a table which slides to and fro to feed or supply each sheet of paper separately into his machine; also needle bars. or holders, to present needles with the requisite threads, for stiching such sheets as they are supplied with in succession. He has, moreover, a series of holding fingers, or pincers, suitably provided with motions, to enable them to advance and clasp the needles, draw them through the sheets of paper, and return them into their respective holders, after threading or stitching the sheet; lastly, there are arms or levers for delivering each sheet regularly upon the top of the preceding sheets, in order to form a collection or book of such sheets, ready for boarding or finishing. A minute description of the whole apparatus, with plates, is given in *Newton's Journal*, C. S. xxiii. 157.

BORACIC ACID.

		1841.	1842.	1843.	1834.
Quantities imported	cwts.	—	7,333	14,986	15,060
Quantities exported	cwts.	—	1	22	620
Retained for consumption . . .	cwts.	—	7,245	13,717	15,953
Nett revenue	£.	3,193	798	361	422

The duty was repealed in 1845.

BORACIC ACID LAGOONS. Before the discovery of this acid in the time of the Grand Duke Leopold I., by the chemist Hæfer, the fetid odor developed by the sulphuretted hydrogen gas, and the disruptions of the ground occasioned by the appearance of new *Soffioni* or vents of vapor, had made the natives regard them as a diabolical scourge, which they sought to remove by priestly exorcisms; but since science has explained the phenomena, the *fumachi* have become a source of public prosperity, and, were they to cease would be prayed to return. The vapors which issue from these lakes keep the waters always at a boiling temperature; hence, after impregnation for 20 or 30 hours by the steams of the highest lake, they draw off the waters into a second lake to suffer a fresh impregnation. Thence they are drawn into a third, and so on till, they reach the lowest receptacle. In this passage, they get charged with one-half per cent. of boracic acid. They are then concentrated in leaden reservoirs, by the heat of the vapors themselves.

The liquid, after having filled the first compartment, is diffused very gradually into the second, then into the third, and successively to the last, where it reaches such a state of concentration that it deposits the crystallized acid; the workmen remove it immediately by means of wooden scrapers. This mode of gradual concentration is very ingenious, and requires so few hands that it may almost be said that the acid is obtained without expense. From 1818 to 1845 the quantity of acid manufactured was 33,349,095 Tuscan pounds. From 1839 to 1845 the mean quantity has been 2,500,000 pounds.

Thus in estimating the product at 7,500 pounds per day, the quantity of saturated water upon which they operate is 1,500,000 lbs. daily, and annually 547,500,000 lbs.

This labor brings to Tuscany ten millions of francs: it is surprising that it should have remained unproductive for so many ages, and that it should have been reserved for the skill of M. Dardarel, now Count of Mote Corboli,—before 1818 a simple wandering merchant, entirely unacquainted with scientific researches, to discover the nature of the fugitive vapors, and render them a source of inexhaustible wealth.

The violence with which the scalding vapors escape gives rise to muddy explosions when a lake has been drained by turning its waters into another lake. The mud is then thrown out, as solid matters are ejected from volcanoes, and there is formed in the bottom of the lake a crowd of those little cones of eruption, whose activity and play are generally from 120° to 145° Centigrade, and the clouds which they form in the lagoons constitute true natural barometers, whose greater or less density rarely disappoints the predictions that they announce.

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BORAX. A native saline compound of boracic acid and soda, found abundantly in Thibet and in South America. The crude product from the former locality was imported into Europe under the name of *tincal*, and was purified from some adhering fatty matter by a process kept a long time secret by the Venetians and the Dutch, and which consisted chiefly in boiling the substance in water with a little quicklime.

Gmelin found borax, in prismatic crystals, to contain 46·6 per cent. of water; and Arvredson, in the calcined state, to consist of 68·9 of acid and 31·1 soda, in 100 parts M. Payen describes an octahedral borax, which contains only 30·64 per cent. of water, and is therefore preferred by the brasiers in their soldering processes.

Borax has a sweetish, somewhat lixivial taste, and affects vegetable colors like an alkali; it is soluble in 12 parts of cold and 2 of boiling water. It effloresces and becomes opaque in a dry atmosphere, and appears luminous, by friction, in the dark. It melts at a heat a little above that of boiling water, and gives out its water of crystallization, after which it forms a spongy mass, called calcined borax. The octahedral borax, which is prepared by crystallization, in a solution of 1·256 sp. gr., kept up at 145° F., is not efflorescent. When borax is ignited, it fuses into a glassy-looking substance.

The following is the improved mode of purifying borax. The crude crystals are to be broken into small lumps, and spread upon a filter lined with a lead grating, under which a piece of cloth is stretched upon a wooden frame. The lumps are piled up to the height of 12 inches, and washed with small quantities of a caustic soda ley of 5° B. (sp. gr. 1·033) until the liquor comes off nearly colorless; they are then drained, and put into a large copper of boiling water, in such quantities that the resulting solution stands 20° B. (sp. gr. 1·160.) Carbonate of soda, equivalent to 12 per cent. of the borax, must now be added; the mixed solution is allowed to settle, and the clear liquid syphoned off into crystallizing vessels. Whenever the mother waters get foul, they must be evaporated to dryness in cast-iron pots, and roasted, to burn away the viscid coloring matter.

Borax is sometimes adulterated with alum and common salt; the former addition may be readily detected by a few drops of water of ammonia, which will throw down its alumina; and the latter by nitrate of silver, which will give with it a precipitate insoluble in nitric acid.

The native boracic acid obtained from the lakes of Tuscany, which has been manufactured in France into borax, has greatly lowered the price of this article of commerce. When MM. Payen and Cartier first began the business, they sold the crystals at the same price as the Dutch, viz., 7 francs the kilogramme ($2\frac{1}{5}$ lbs. avoird.); but, in a few years, they could obtain only 2 francs and 60 centimes, in consequence of the market getting overstocked. The annual consumption of France in 1823 was 25,000 kilos., and the quantity produced in M. Payen's works was 50,000. The mode of making borax from the acid is as follows:—The lake water is evaporated in graduation houses, and then concentrated in boilers till it crystallizes. In that state it is carried to Marseilles. About 500 kilogrammes of water are made to boil in a copper, and 600 kilogrammes of crystallized carbonate of soda are dissolved in it by successive additions of 20 kilogrammes. The solution being maintained at nearly the boiling point, 500 kilogrammes of the crystallized boracic acid of Tuscany are introduced, in successive portions. At each addition of about 10 kilogrammes, a lively effervescence ensues, on which account the copper should be of much greater capacity than is sufficient to contain the liquors. When the whole acid has been added, the fire must be damped by being covered up with moist ashes, and the copper must be covered with a tight lid and blankets, to preserve the temperature uniform. The whole is left in this state during 30 hours; the clear liquor is then drawn off into shallow crystallizing vessels of lead, in which it should stand no higher than 10 or 12 inches, to favor its rapid cooling. At the end of three days in winter, and four in summer, the crystallization is usually finished. The mother water is drawn off, and employed, instead of simple water, for the purpose of dissolving fresh crystals of soda. The above crystals are carefully detached with chisels, redissolved in boiling water, adding for each 100 kilos., 10 kilos. of carbonate of soda. This solution marks 20° B. (sp. gr. 1·160); and, at least, one ton (1000 kilos.) of borax should be dissolved at once, in order to obtain crystals of a marketable size. Whenever this solution has become boiling hot, it must be run off into large crystallizing lead chests of the form of inverted truncated pyramids, furnished with lids, enclosed in wooden frames, and surrounded with mats to confine the heat. For a continuous business, there should be at least 18 vessels of this kind; as the solution takes a long time to complete its crystallization, by cooling to 30° C. (86° F.) The borax crystals are taken out with chisels, after the liquor has been drawn off, and the whole has become cold.

One hundred parts of the purest acid, usually extracted from the lakes of Tuscany, contain only fifty parts of the real boracic acid, and yield no more, at the utmost, than 140 or 150 of good borax.

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According to Wittstein, the commercial boracic acid is composed as follows:—

Sulphate of manganese	A trace
iron	0·365
alumina	0·320
lime	1·018
magnesia	2·632
ammonia	8·508
soda	0·917
potash	0·369
salammonia	0·298
silica (in solution)	1·200
sulphuric acid (combined with the boracic)	1·322
crystallizable boracic acid	76·494
Water	6·557
	100·000

Dry borax acts on the metallic oxides at a high temperature, in a very remarkable manner, melting and vitrifying them into beautiful colored glasses. On this account it is a most useful reagent for the blowpipe. Oxide of chrome tinges it of an emerald green; oxide of cobalt, an intense blue; oxide of copper, a pale green; oxide of tin, opal; oxide of iron, bottle green and yellow; oxide of manganese, violet; oxide of nickel, pale emerald green. The white oxides impart no color to it by themselves. In the fusion of metals borax protects their surface from oxidizement, and even dissolves away any oxides formed upon them; by which twofold agency it becomes an excellent flux, invaluable to the goldsmith in soldering the precious metals, and to the brazier in soldering copper and iron.

Borax absorbs muriatic and sulphureous acid gases, but no others, whereby it becomes, in this respect, a useful means of analysis.

The strength or purity of borax may be tested by the quantity of sulphuric acid requisite to neutralize a given weight of it, as indicated by tincture of litmus.

When mixed with shellac in the proportion of one part to five, borax renders that resinous body soluble in water, and forms with it a species of varnish.

Boracic acid is a compound of 31·19 of boron and 68·81 oxygen, in 100 parts. Its prime equivalent referred to oxygen 100, is 871·96.

The following process for refining the native Indian borax, or tincal, has been published by MM. Robiquet and Marchand:—

It is put into large tubs, covered with water for 3 or 4 inches above its surface, and stirred through it several times during six hours. For 400 lbs. of the tincal there must now be added 1 lb. of quicklime diffused through two quarts of water. Next day the whole is thrown upon a sieve, to drain off the water with the impurities, consisting, in some measure, of the fatty matter combined with the lime, as an insoluble soap. The borax, so far purified, is to be dissolved in 2½ times its weight of boiling water, and 8 lbs. of muriate of lime are to be added for the above quantity of borax. The liquor is now filtered, evaporated to the density of 18° or 20° B. (1·14 to 1·16 sp. grav.), and set to crystallize in vessels shaped like inverted pyramids, and lined with lead. At the end of a few days, the crystallization being completed, the mother waters are drawn off, and the crystals are detached and dried. The loss of weight in this operation is about 20 per cent.

		1841.	1842.	1843.	1844.
Quantities imported	cwts.	—	3581	847	1427
Quantities exported	cwts.	—	2435	2940	3637
Retained for consumption	cwts.	—	7798	889	349
Nett revenue	£	866	161	5	4

The duty on borax has been repealed.

Borax, Dry. A considerable saving of expense in manufacturing borax, and a more ready application of the borax to use, are proposed by Saulter, as follows:—Take about 38 parts of pure crystallized boracic acid, pounded and sifted; mix them well with 45 parts of crystals of carbonate of soda in powder; expose the mixture upon wooden shelves to heat in a stove room; and rake it up from time to time. The boracic acid and the alkali thus get combined, while the carbonic acid and water are expelled; and a perfect dry borax is obtained.

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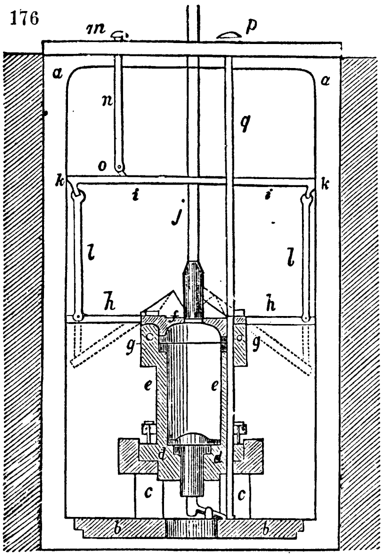


BOTTLE MANUFACTURE. The following mechanism for moulding bottles forms the subject of a patent obtained by Henry Rickets of Bristol, in 1822. *Fig.* 176 is a section of the apparatus, consisting of a square frame, *a a*, of iron or wood; this is fixed in a pit formed in the floor; *b b* is the base of the frame, with an aperture for knocking up the bottom of the bottle; *c c* are four legs secured to the frame-floor *b*, upon which the mould is supported. The platform or stand of the mould *d d* has an opening in its centre for the introduction of the bottom of the mould, which is raised against the bottom of the bottle by the knocker-up; *e e* are the sides of the mould; and *f f* is the top of the mould in two pieces, turning over upon the joints at *g g*, so as to form the neck of the bottle; *h h* are levers or arms for raising and depressing the top pieces; *i i* is a horizontal shaft or axle, turning in bearings at each end, from which shaft two levers, *k k*, extend; these levers are connected by upright rods, *l l*, to the levers or arms, *h h*, of the top pieces *f f*. The weight of the arms *h h*, and rods *l l*, will, by their gravity, cause the top pieces to open, as shown by the dotted lines; in this situation of the mould, the melted glass is to be introduced by a tube as usual. The workman then steps with one foot upon the knob *m*, which forces down the rod *n*, and by means of a short lever *o*, extending from the shaft *i*, forces down the top pieces *f*, and closes the mould, as seen in the figure; the glass is then made to extend itself to the shape of the mould, by blowing as usual, so as to form the bottle, and the workman at this time putting his other foot upon the knob *p*, depresses the rod *q*, and hence raises the bottom of the mould by means of the knocker-up, *r*, so as to form the bottom of the bottle.

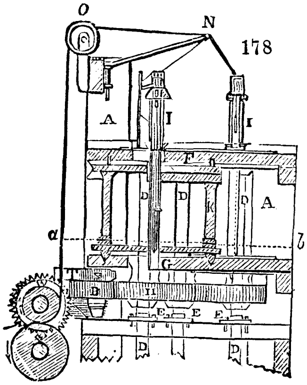
At the bottom of the mould a ring is introduced of any required thickness, for the purpose of regulating the capacity of the bottle; upon which ring it is proposed to raise letters and figures, as a mould to imprint the maker's name and the size of the bottle. These moulds can be removed and changed at pleasure. Under the knob *p*, a collar or washer is to be introduced, of any required thickness, to regulate the knocking up of the bottom, by which a perfect symmetry of form is presented. In order to make bottles of different sizes or forms, the mould is intended to be removed, and its place supplied by another mould of different dimensions and figure; the lower parts of all the moulds being made to fit the same frame. Such a mould ought to be prescribed by legislative enactment, with an excise stamp to define the capacity of every bottle, and thereby put an end to the interminable frauds committed in the measure of wine and all other liquors sold by the bottle.

BOUGIE. A smooth, flexible, elastic, slender cylinder, introduced into the urethra, rectum, or œsophagus, for opening or dilating it, in cases of stricture and other diseases. The invention of this instrument is claimed by Aldereto, a Portuguese physician, but its form and uses were first described by his pupil Amatus, in the year 1554. Some are solid, and some hollow; some corrosive, and some mollifying. They generally owe their elasticity to linseed oil, inspissated by long boiling, and rendered drying by litharge. This viscid matter is spread upon a very fine cord or tubular web of cotton, flax, or silk, which is rolled upon a slab when it becomes nearly solid by drying, and is finally polished in the same way.

Pickel, a French professor of medicine, published the following recipe for the composition of bougies. Take 3 parts of boiled linseed oil, one part of amber, and one of oil of turpentine; melt and mix these ingredients well together, and spread the compound at three successive intervals upon a silk cord or web. Place the pieces so coated in a stove heated to 150° F.; leave them in it for 12 hours, adding 15 or 16 fresh layers in succession, till the instruments have acquired the proper size. Polish them first with pumice-stone, and finally smooth with tripoli and oil. This process is the one still employed in Paris, with some slight modifications; the chief of which is dissolving in the oil one twentieth of its weight of caoutchouc to render the substance more solid. For this purpose the caoutchouc must be cut into slender shreds, and added gradually to the hot oil. The silk tissue must be fine and open, to admit of the composition entering freely among its filaments. Each successive layer ought to be dried first in a stove, and then in the open air, before another is applied. This process takes two months for its completion, in forming the best bougies called *elastic;* which ought to bear twisting round the finger without cracking or scaling, and extension without giving way, but retracting when let go. When the bougies are to be hollow, a mandril of iron wire, properly bent with a ring at one end, is introduced into the axis of the silk tissue. Some bougies are made with a hollow axis of tin foil rolled into a slender tube. Bougies are also made entirely of caoutchouc, by the intervention of a solution of this substance in sulphuric ether, a menstruum sufficiently cheap in France, on account of the low duty upon alcohol. There are medicated bougies, the composition of which belongs to surgical pharmacy. The manufacture of these instruments of various kinds forms a separate and no inconsiderable branch of industry at Paris. MM. Feburger and Lamotte are eminent in this line.

BRACES. (*Bretelles*, Fr.; *Hosenträger*, Germ.) Narrow fillets or bands of leather or textile fabric, which pass over the shoulders, and are attached behind and before to the waistbands of pantaloons and trousers, in the act of wearing them, for supporting their weight, and *bracing* them up to the body. It is a useful modern invention, superseding the necessity of girding the belly with a tight girdle, as in former times.

BRAIDING MACHINE. (*Machine à lacets*, Fr.; *Bortenwerkerstuhl*, Germ.) This being employed not only to manufacture stay-laces, braid, and upholsterers' cord, but to cover the threads of caoutchouc for weaving brace-bands, deserves a description in this work. Three threads at least are required to make such a knitted lace, but 11, 13, or 17, and even 29 threads are often employed, the first three numbers being preferred. They are made by means of a frame of a very ingenious construction, which moves by a continuous rotation. We shall describe a frame with 13 threads, from which the structure of the others may be readily conceived. The basis of the machine consists of four strong wooden uprights, A, *figs*. 177, 178, 179, occupying the four angles of a rectangle, of which one side is 14 inches long, the other 18 inches, and the height of the rectangle about 40 inches. *Fig*. 177 is a section in a horizontal plane, passing through the line *a b* of *fig*. 178, which is a vertical section in a plane passing through the centre of the machine C, according to the line *c d*, *fig*. 177. The side X is supposed to be the front of the frame; and the opposite side, Y, the back. B, six spindles or skewers, numbered, from 1 to 6, placed in a vertical position upon the circumference of a circle, whose centre coincides with that of the machine at the point C. These six spindles are composed, 1. Of so many iron shafts or axes D, supported in brass collets E (*fig*. 178), and extended downwards within six inches of the ground, where they rest in brass steps fixed upon a horizontal beam. 2. Wooden heads, made of horn-beam or nut-tree, placed, the first upon the upper end of each spindle, opposite the cut-out beam F, and the second opposite the second beam G. 3. Wooden-toothed wheels, H, reciprocally working together, placed between the beam G and the collet-beam E. The toothed wheels and the lower heads for each spindle are in one piece.



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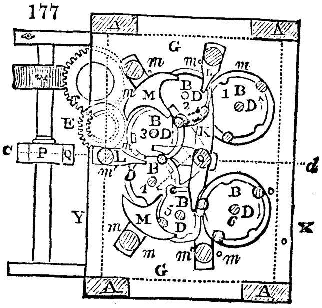
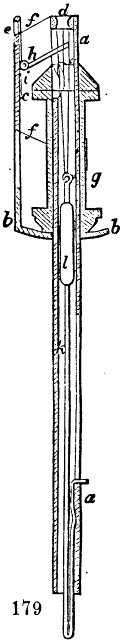


The heads and shafts of the spindles No. 1 and 6, are one fifth stronger than those of the other spindles; their heads have five semicircular grooves, and wheels of 60 teeth, while the heads of the others have only four grooves, and wheels of 48 teeth; so that the number of the grooves in the six spindles is 26, one half of which is occupied with the stems of the puppets I, which carry the 13 threads from No. 1 to 13. The toothed wheels, which give all the spindles a simultaneous movement, but in different directions, are so disposed as to bring their grooves opposite to each other in the course of rotation.

K, the middle winglet, triple at bottom and quintuple at top, which serves to guide the puppets in the direction they ought to pursue.

L, three winglets, single at top and bottom, placed exteriorly, which serve a like purpose.

M, two winglets, triple at bottom and single at top, placed likewise exteriorly, and which serve the same purposes as the preceding; *m* are iron pins inserted in the cut-out beam G, which serve as stops or limits to the oscillations of the exterior winglets.



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Now, if by any moving power (a man can drive a pair) rotation be impressed upon the large spindle No. 1, in the direction of the arrow, all the other spindles will necessarily pursue the rotatory movement indicated by the respective arrows. In this case, the 13 puppets working in the grooves of the heads of the spindles will be carried round simultaneously, and will proceed each in its turn, from one extremity of the machine to the opposite point, crossing those which have a retrograde movement. The 13 threads united at the point N, situated above the centre of the machine, will form at that point the braid, which, after having passed over the pulley *o*, comes between the two rollers P Q, and is squeezed together, as in a flatting-mill, where the braid is calendered at the same time that it is delivered. It is obvious that the roller P receives its motion from the toothed wheel of the spindle No. 3, and from the intermediate wheels R, S, T, as well as from the endless screw *z*, which drives at proper speed the wheel W, fixed upon the shaft of the roller P.

The braid is denser in proportion as the point N is less elevated above the tops of the puppets; but in this case, the eccentric motion of these puppets is much more sensible in reference to that point towards which all the threads converge than when it is elevated. The threads, which must be always kept equally stretched by means of a weight, as we shall presently see, are considerably strained by the traction, occasioned by the constantly eccentric movement of the puppets. From this cause, braiding machines must be worked at a moderate velocity. In general, for fine work, 30 turns of the large spindle per minute are the utmost that can safely be made.

The puppet or spindle of this machine, being the most importan piece, I have represented it in section, upon a scale one fourth of its actual size, *fig.* 179. It is formed of a tube, *a*, of strong sheet iron well brazed; *b* is a disc, likewise of sheet iron, from which a narrow fillet, *c*, rises vertically as high as the tube, where both are pierced with holes, *d e*, through which the thread *f* is passed, as it comes from the bobbin, *g*, which turns freely upon the tube *a*. The top of this bobbin is conical and toothed. A small catch or detent, *h*, moveable in a vertical direction round *i*, falls by its own weight into the teeth of the crown of the bobbin, in which case this cannot revolve; but when the detent is raised so far as to disengage the teeth, and at the same time to pull the thread, the bobbin turns, and lets out thread till the detent falls back into these same teeth.

A skewer of iron wire, *k*, is loaded with a small weight, *l*, melted upon it. The top of this skewer has an eye in it, and the bottom is recurved as is shown in *fig.* 179, so that supposing the thread comes to break, this skewer falls into the actual position in the figure, where we see its lower end extending beyond the tube *a*, by about ¼ of an inch; but as long as the thread is unbroken, the skewer *k*, which serves to keep it always tense, during the eccentric movement of the puppet, does not pass out below the tube.

This disposition has naturally furnished the means of causing the machine to stop, whenever one of the threads breaks. This inferior protrusion of the skewer pushes in its progress a detent, which instantly causes the band to slide from the driving pulley to the loose pulley. Thus the machine cannot operate unless all the threads be entire. It is the business of the operative, who has 3 or 4 under her charge, to mend the threads as they break, and to substitute full bobbins for empty ones, whenever the machine is stopped.

The braiding frame, though it does not move quickly, makes a great deal of noise, and would make still more, were the toothed wheels made of metal instead of wood. For them to act well, they should be made with the greatest precision, by means of appropriate tools for forming the teeth of the wheels, and the other peculiar parts.

BRAN. (*Son*, Fr.; *Kleie*, Germ.) The husky portion of ground wheat, separated by the bolter from the flour. It is advantageously employed by the calico printers, in the clearing process, in which, by boiling in bran-water, the coloring matters adhering to the non-mordanted parts of maddered goods, as well as the dun matters which cloud the mordanted portions, are removed. A valuable series of researches concerning the operation of bran in such cases was made a few years ago by that distinguished chemist and calico printer, M. Daniel Kœchlin Schouch, and published in the ninth number of the Bulletin de la Société Industrielle de Mulhausen. Nine sets of experiments are recorded, which justified the following conclusions.

1. The dose of two bushels of bran for 10 pieces of calico is the best, the ebullition being kept up for an hour. A boil for the same time in pure water had no effect in clearing either the grounds or the figures.

2. Fifteen minutes boiling are sufficient when the principal object is to clear white grounds, but in certain cases thirty minutes are requisite to brighten the dyed parts. If, by increasing the charge of bran, the time of the ebullition could be shortened, it would be in some places, as Alsace, an economy; because for the passage of ten pieces through a copper or vat heated with steam, 1 cwt. of coal is consumed in fuel which costs from 2½ to 3 francs, while two bushels of bran are to be bought for one franc.

3. By increasing the quantity of water from 12 to 24 hectolitres with two bushels of bran, the clearing effect upon the ten pieces was impaired. It is therefore advantageous not to use too much water.

4. Many experiments concur to prove that flour is altogether useless for the clearing boil, and that finer bran is inferior for this purpose to the coarser.

5. The white ground of the calicoes boiled with wheat bran, are distinguishable by their superior brightness from that of those boiled with rye bran, and especially with barley bran; the latter having hardly any effect.

6. There is no advantage in adding soap to the bran boil; though a little potash or soda may be properly introduced when the water is calcareous.

7. The pellicle of the bran is the most powerful part, the flour and the starch are of no use in clearing goods, but the mucilage which forms one third of the weight of the bran has considerable efficacy, and seems to act in the following way. In proportion as the mucilaginous substance dissolves the coloring and tawny matters upon the cloth, the husky surface attracts and fixes upon itself the greater part of them. Accordingly, when used bran is digested in a weak alkaline bath, it gives up the color which it had absorbed from the cloth.

The following chemical examination of bran is interesting. A pound of it was boiled at successive times with water; the decoctions, being filtered, let fall in cooling a grayish deposite, which was separated by decantation. The clear liquor afforded by evaporation to dryness four ounces of a brownish, brittle matter, composed chiefly of mucilage, a little gluten, and starch. The gray deposite of the above filtered liquor amounted to half an ounce. Nine ounces of the cortical portion of the bran were obtained. The loss amounted to 2½ ounces, being in some measure the hygrometric water of the bran itself.

When boiled with distilled water, goods are cleared pretty well without bran. Certain delicate dyes must be boiled only a few minutes in a strong decoction of bran previously made.

BRANDY. The name given in this country to ardent spirits distilled from wine, and possessed of a peculiar taste and flavor, due to a minute portion of a peculiar volatile oil. Each variety of alcohol has an aroma characteristic of the fermented substance from which it is procured; whether it be the grape, cherries, sugar-cane, rice, corn, or potatoes; and it may be distinguished even as procured from different growths of the vine. The brandies of Languedoc, Bordeaux, Armagnac, Cognac, Aunis, Saintonge, Rochelle, Orleans, Barcelona, Naples, &c. being each readily recognisable by an experienced dealer.

Aubergier showed, by experiments, that the disagreeable taste of the spirits distilled from the *marc* of the grape is owing to an essential oil, contained in the skin of the grape; and found that the oil, when insulated, is so energetic that a few drops are sufficient to taint a pipe of 600 litres of fine flavored spirit.

The most celebrated of the French brandies, those of Cognac and Armagnac, are slightly rectified to only from 0·935 to 0·922; they contain more than half their weight of water, and come over therefore highly charged with the fragrant essential oil of the husk of the grape. When, to save expense of carriage, the spirit is rectified to a much higher degree, the dealer, on receiving it at Paris, reduces it to the market proof by the addition of a little highly-flavored weak brandy and water; but he cannot in this way produce so finely-flavored a spirit, as the weaker product of distillation of the Cognac wine. If the best Cognac brandy be carefully distilled at a low heat, and the strong spirit be diluted with water, it will be found to have suffered much in its flavor.

Genuine French brandy evinces an acid reaction with litmus paper, owing to a minute portion of vinegar; it contains, besides, some acetic ether, and, when long kept in oak

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casks, a little astringent matter. The following formula may be proposed for converting a silent or flavorless corn spirit, into a factitious brandy. Dilute the pure alcohol to the proof pitch, add to every hundred pounds weight of it from half a pound to a pound of argol (crude winestone) dissolved in water, a little acetic ether, and French wine-vinegar, some bruised French plums, and flavor-stuff from Cognac; then distil the mixture with a gentle fire, in an alembic furnished with an agitator.

The spirit which comes over may be colored with nicely burned sugar (caramel) to the desired tint, and roughened in taste with a few drops of tincture of catechu or oak-bark.

The above recipe will afford a spirit free from the deleterious drugs too often used to disguise and increase the intoxicating power of British brandies; one which may be reckoned as wholesome as alcohol, in any shape, can ever be.

BRASS. (*Laiton, cuivre jaune*, Fr.; *Messing*, Germ.) An alloy of copper and zinc. It was formerly manufactured by cementing granulated copper, called *bean-shot*, or copper clippings, with calcined calamine (native carbonate of zinc) and charcoal, in a crucible, and exposing them to bright ignition. Three parts of copper were used for three of calamine and two of charcoal. The zinc reduced to the metallic state by the agency of the charcoal, combined with the copper, into an alloy which formed, on cooling, a lump at the bottom of the crucible. Several of these, being remelted and cast into moulds, constituted ingots of brass for the market. James Emerson obtained a patent, in 1781, for making brass by the direct fusion of its two metallic elements, and it is now usually manufactured in this way.

It appears that the best proportion of the constituents to form fine brass is one prime equivalent of copper$=63\frac{1}{2}+$one of zinc$=32\cdot3$; or very nearly 2 parts of copper to 1 of zinc. The bright gold colored alloy, called Prince's, or Prince Rupert's metal, in this country, consists apparently of two primes of zinc to one of copper, or of nearly equal parts of each. Brass, or hard solder, consists of two parts of brass and one of zinc melted together, to which a little tin is occasionally added; but when the solder must be very strong, as for brass tubes that are to undergo drawing, two thirds of a part of zinc are used for two parts of brass. Mosaic gold, according to the specification of Parker and Hamilton's patent, consists of 100 parts of copper, and from 52 to 55 of zinc; which is no atomic proportion. Bath metal is said to consist of 32 parts of brass and 9 parts of zinc.

The button manufacturers of Birmingham make their *platin* with 8 parts of brass and 5 of zinc; but their cheap buttons with an alloy of copper, tin, zinc, and lead.

Red brass, the Tombak of some, (not of the Chinese, for this is white copper,) consists of more copper and less zinc than go to the composition of brass; being from $2\frac{1}{2}$ to 8 or 10 of the former to 1 of the latter. At the famous brass works of Hegermühl, to be presently described, 11 parts of copper are alloyed with 2 of zinc into a red brass, from which plates are made that are afterwards rolled into sheets. From such an alloy the Dutch foil, as it is called, is manufactured at Nürnberg; Pinchbeck, Similor, Mannheim gold, are merely different names of alloy similar to Prince's metal. The last consists of 3 of copper and 1 of zinc, separately melted, and suddenly incorporated by stirring.—*Wiegleb.*

In the process of alloying two metals of such different fusibilities as copper and zinc, a considerable waste of the latter metal by the combustion, to which it is so prone, might be expected; but, in reality, their mutual affinities seem to prevent the loss, in a great measure, by the speedy absorption of the zinc into the substance of the copper. Indeed, copper plates and rods are often *brassed* externally by exposure, at a high temperature, to the fumes of zinc, and aftewards laminated or drawn. The spurious gold wire of Lyons is made from such rods. Copper vessels may be superficially converted into brass by boiling them in dilute muriatic acid containing some wine-stone and zinc amalgum.

The first step in making brass is to plunge slips of copper into melted zinc till an alloy of somewhat difficult fusion be formed, to raise the heat, and add the remaining proportion of the copper.

The brass of the first fusion is broken to pieces, and melted with a fresh quantity of zinc, to obtain the finished brass. Each melting takes about 8 or 9 hours. The metal is now cast into plates, about 40 inches long by 26 inches broad, and from one third to one half inch thick. The moulds are, in this case also, slabs of granite mounted in an iron frame. Granite appears to be preferred to every thing else as a mould, because it preserves the heat long, and by the asperities of its surface, it keeps hold of the clay lute applied to secure the joinings.

The cast plates are most usually rolled into sheets. For this purpose they are cut into ribands of various breadths, commonly about $6\frac{1}{2}$ inches. The cylinders of the brass rolling-press are generally 46 inches long, and 18 inches in diameter. The

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ribands are first of all passed cold through the cylinders; but the brass soon becomes too hard to laminate. It is then annealed in a furnace, and, after cooling, is passed afresh through a rolling press. After paring off the chipped edges, the sheets are laminated two at a time: and if they are to be made very thin, even eight plates are passed through together. The brass in these operations must be annealed 7 or 8 times before the sheet arrives at the required thinness. These successive heatings are very expensive; and hence they have led the manufacturers to try various plans of economy. The annealing furnaces are of two forms, according to the size of the sheets of brass. The smaller are about 12 feet long, with a fire-place at each end, and about 13 inches wide. The arch of the furnace has a cylindrical shape, whose axis is parallel to its small side. The hearth is horizontal, and is made of bricks set on edge. In the front of the furnace there is a large door, which is raised by a lever, or chain, and counterweight, and slides in a frame between two cheeks of cast iron. This furnace has, in general, no chimney, except a vent slightly raised above the door, to prevent the workmen being incommoded by the smoke. Sometimes the arch is perforated with a number of holes. The sheets of brass are placed above each other, but separated by parings, to allow the hot air to circulate among them, the lowest sheet resting upon two bars of cast iron placed lengthwise.

The large furnaces are usually 32 feet long, by 6½ feet wide, in the body, and 3 feet at the hearth. A grate, 13 inches broad, extends along each side of the hearth, through its whole length, and is divided from it by a small wall, 2 or 3 inches high. The vault of the furnace has a small curvature, and is pierced with 6 or 8 openings, which allow the smoke to pass off into a low bell-chimney above. At each end of the furnace there is a cast-iron door, which slides up and down in an iron frame, and is poised by a counterweight. On the hearth there is a kind of railway, composed of two iron bars, on the grooves of which the carriage moves with its loads of sheets of brass.

These sheets, being often 24 feet long, could not be easily moved in and out of the furnace; but as brass laminates well in the cold state, they are all introduced and moved out together. With this view, an iron carriage is framed with four bars, which rest on four wheels. Upon this carriage, of a length nearly equal to that of the furnace, the sheets are laid, with brass parings between them. The carriage is then raised by a crane to a level with the furnace, and entered upon the grooved bars which lie upon the hearth. That no heat may be lost, two carriages are provided, the one being ready to put in as the other is taken out; the furnace is meanwhile uniformly kept hot. This method, however convenient for moving the sheets in and out, wastes a good deal of fuel in heating the iron carriage.

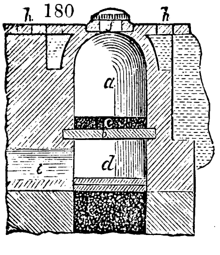
The principal places in which brass is manufactured on the great scale in England, are Bristol, Birmingham, and Holywell, in North Wales.

The French writers affirm, that a brass, containing 2 *per cent.* of lead, works more freely in the turning lathe, but does not hammer so well as a mere alloy of copper and zinc.

At the brass manufactory of Hegermühl, upon the Finon canal near Potsdam, the following are the materials of one charge; 41 pounds of old brass, 55 pounds refined copper (gahrkupfer) granulated; and 24 pounds of zinc. This mixture, weighing 120 pounds, is distributed into four crucibles, and fused in a wind furnace with pitcoal fuel. The waste varies from 2½ to 4 pounds upon the whole.

Fig. 180 represents the furnace as it was formerly worked there with charcoal; *a*, the laboratory in which the crucibles were placed. It was walled with fire-bricks. The foundations, and the filling-in walls were formed of stone rubbish, as being bad conductors of heat; sand and ashes may be also used; *b*, cast iron circular grating plates pierced with 12 holes (see *fig.* 181), over them a sole of loam, *c*, is beat down, and perforated with holes, corresponding to those in the iron discs; *d*, the ash pit; *e*, the *bock*, a draught flue which conducts the air requisite to the combustion, from a sunk tunnel, in communication with several melting furnaces. The terrace or crown of the furnace, *f*, lies on a level with the foundery floor, *h h*, and is shut with a tile of fire-clay, *g*, which may be moved in any direction by means of hooks and eyes in its binding iron ring

180



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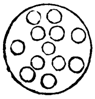

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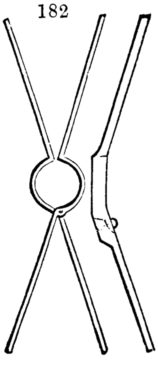
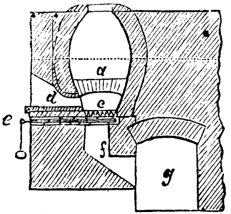


Fig. 182, the tongs for putting in and taking out the charges, as viewed from above and from the side.

Figs. 183, 184, represent the furnaces constructed more recently for the use of pitcoal fuel; *fig.* 183 being an upright section, and *fig.* 184, the ground plan. In this furnace the crucibles are not surrounded with the fuel, but they receive the requisite melting heat from the flame proceeding from the grate upon which it is burned. The crucibles stand upon seven binding arches, *a*, which unite in the middle at the keystone *b*, *fig.* 186; between the arches are spaces through which the flame rises from the grate *c*; *d* is the fire door; *e*, a sliding tile or damper for regulating or shutting off the air-draught; *f*, an inclined plane, for carrying off the cinders that fall through the grate, along the draught tunnel *g*, so that the air in entering below may not be heated by them.

183



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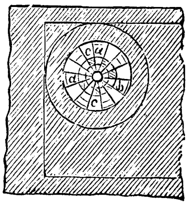

The crucibles are 16 inches deep, 9½ wide at the mouth, 6½ at the bottom; with a thickness in the sides of 1 inch and 1½ below; they stand from 40 to 50 meltings. The old brass, which fills their whole capacity, is first put in and melted down; the crucibles are now taken out and are charged with the half of the zinc in pieces of from 1 to 3 cubic inches in size, covered over with coal ashes; then one-half of the copper charge is introduced, again coal-dust; and thus the layers of zinc and copper are distributed alternately with coal-ashes betwixt them, till the whole charge gets finally fused. Over all, a thicker layer of carbonaceous matter is laid, to prevent oxidizement of the brass. Eight crucibles filled in this way are put into the furnace between the 11 holes of the grate shelf; and over them two empty crucibles are laid to be heated for the casting operation. In from 3½ to 4 hours the brass is ready to be poured out. Fifteen English bushels of coals are consumed in one operation; of which six are used at the introduction of the crucibles, and four gradually afterwards.

When sheet brass is to be made the following process is pursued:—

An empty crucible, called a *caster* (*giesser*), is taken out of the furnace through the crown with a pair of tongs, and is kept red hot by placing it in a hollow hearth (*mundal*) surrounded with burning coals; into this crucible the contents of four of the melting pots are poured; the dross being raked out with an iron scraper. As soon as the melting pot is emptied, it is immediately re-charged in the manner above described, and replaced in the furnace. The surface of the melted brass in the *caster* is swept with the stump of a broom, then stirred about with the iron rake, to bring up any light foreign matter to the surface, which is then skimmed with a little scraper; the crucible is now seized with the casting tongs, and emptied in the following way:—

The mould or *form* for casting sheet brass consists of two slabs of granite, *a a*, *figs* 185, 186. They are 5½ feet long; 3 feet broad, 1 foot thick, and for greater security, girt with iron bands, *b b*, 2 inches broad, 1½ thick, and joined at the four corners with bolts and nuts. The mould rests upon an oaken block, *c*, 3½ feet long, 2⅙ broad, and 1¼ thick, which is suspended at each end upon gudgeons, in bearing blocks, placed under the foundry floor, *d d*, in the casting pit, *e e*. This is lined with bricks; and is 6¾ feet long, 5½ broad, and 2 deep; upon the two long side walls of the pit, the bearing blocks are laid which support the gudgeons. The swing-blocks are 10 inches long, 18 inches broad, 15 inches thick, and are somewhat rounded upon their back edge, so that the casting frame may slope a little to the horizon. To these blocks two cross wooden arms,

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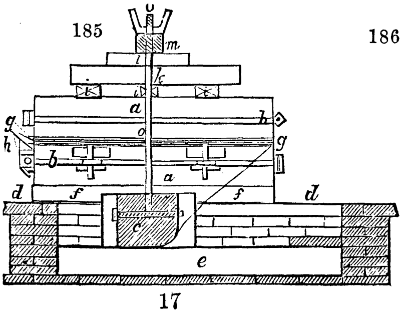

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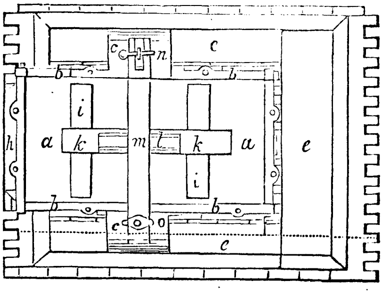
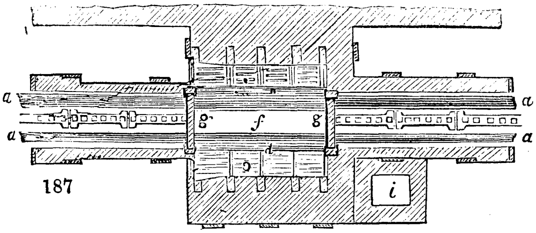


f f, are mortised, upon which the underslab rests freely, but so as to project about 5 inches backwards over the block, to secure an equipoise in the act of casting. *g g* are bars, placed at both of the long sides, and one of the ends, between the slabs, to determine the thickness of the brass-plate. Upon the other slab the gate *h* is fastened, a sheet of iron 6 inches broad, which has nearly the shape of a parallel trapezium (lozenge), and slopes a little towards the horizon. It serves for setting the casting pot upon in the act of pouring out, and renders its emptying more convenient. That gate (*steinmaul*) is coated with a mixture of loam and hair. The upper slab is secured to the under one in its slanting position by an *armor* or binding. This consists of the tension bars of wood, *i k l m*, of the iron bars *n*, (3 to 3½ inches broad, 1½ inch thick, see the top view, *fig.* 186,) of a rod with holes and pins at its upper end, and of the iron screw spindle *o*. The mode in which these parts act may be understood from inspection of the figure. In order to lift the upper slab from the under one, which is effected by turning it round its edge, a chain is employed, suspending two others, connected with the slab. The former passes over a pully, and may be pulled up and down by means of a wheel and axle, or with the aid of a counterweight. Upon each of the two long sides of the slab there are two iron rings, to which the ends of the chains may be hooked. The casting faces of the slab must be coated with a layer of finely ground loam; the thinner the better.

When calamine is employed, ½ cwt. of copper, ¾ cwt. of calamine, and ⅓ the volume of both of charcoal mixed, are put into seven crucibles, and exposed to heat during 11 or 12 hours; the product being from 70 to 72 lbs. of brass.

Brass-Plate Rolling.—At Hegermühl there are two re-heating or annealing furnaces, one larger, 18 feet long, and another smaller, 8½; the hot chamber is separated from the fire place by iron beams, in such a way that the brass castings are played upon by the flames on both their sides. After each passage through the laminating press (rolls) they are heated anew, then cooled and laminated afresh, till they have reached the proper length. The plates are besmeared with grease before rolling.



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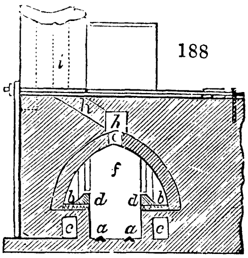

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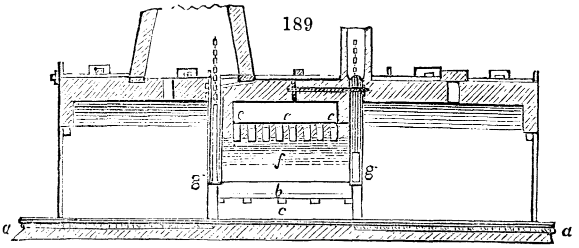

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Fig. 187 shows the ground plan of the furnace and its railway; *fig.* 188 the cross section; and *fig.* 189 the section lengthwise; *a a*, the iron way bars or rails upon the floor of the foundry, for enabling the wheels of the wagon-frame to move readily backwards and forwards; *b b*, the two grates; *c c*, the ash pits; *d d*, the fire beams; *e e e*, vents in the roof of the hot chamber *f*; *g g*, two plates for shutting the hot chamber; *h*, the flue; *i*, the chimney. After the rolling, the sheets covered with a black oxide of copper, are plunged into a mother water of the alum works for a few minutes, then washed in clean water, and lastly, smeared with oil, and scraped with a blunt knife.

In rough brass and brass wares, no less than 16,240 cwts. were manufactured in the Prussian States in the year 1832.

For musical purposes, the brass wire made in Berlin, has acquired great and merited celebrity, but that of Birmingham is now preferred even by foreigners.

Brass Color, for staining glass, is prepared by exposing for several days thin plates of brass upon tiles in the *leer* or annealing arch of the glass-house, till it be oxidized into a black powder, aggregated in lumps. This being pulverized and sifted, is to be again well calcined for several days more, till no particles remain in the metallic state when it will form a fine powder of a russet brown colour. A third calcination must now be given, with a carefully regulated heat; its quality being tested from time to time by fusion with some glass. If it makes the glass swell, and intumesce, it is properly prepared; if not, it must be still farther calcined. Such a powder communicates to glass greens of various tints, passing into turquoise.

When thin narrow strips of brass are stratified with sulphur in a crucible, and calcined at a red heat, they become friable, and may be reduced to powder. This being sifted and exposed upon tiles in a reverberatory furnace for ten or twelve days becomes fit for use, and is capable of imparting a chalcedony, red or yellow tinge to glass by fusion, according to the mode and proportion of using it.

The glass-maker's red colour may be prepared by exposing small plates of brass to a moderate heat in a reverberatory furnace, till they are thoroughly calcined, when the substance becomes pulverulent, and assumes a red colour. It is then ready for immediate use.

Brass Colour, as employed by the colourmen to imitate brass, is of two tints, the red or bronze, and the yellow like gilt brass. Copper filings mixed with red ochre or bole, constitute the former; a powdered brass imported from Germany is used for the latter. Both must be worked up with varnish after being dried with heat, and then spread with a flat camel-hair brush evenly upon the surface of the object. The best varnish is composed of 20 ounces of spirits of wine, 2 ounces of shellac, and 2 ounces of sandarach, properly dissolved. (See Varnish.) Only so much of the brass powder and varnish should be mixed at a time as is wanted for immediate use. (See Bronze Powder.)

Brass Foil. Dutch leaf, called *Knitter* or *Rauschgold* in Germany, is made from a very thin sheet brass, beat out under a hammer worked by water power, which gives 300 or 400 strokes per minute; from 40 to 80 leaves being laid over each other. By this treatment it acquires its characteristic solidity and lustre. See above, the process for converting the copper superficially into brass by the fumes of zinc.

Brass, Yellow. The following table exhibits the composition of several varieties of this species of brass. No. 1. is a cast brass of uncertain origin; 2. the brass of Jemappes; 3. the sheet brass of Stolberg, near Aix-la-Chapelle; 4. and 5. the brass for gilding, according to D'Arcet; 6. the sheet brass of Romilly; 7. English brass wire; 8. Augsburg brass wire; 9. brass wire of Neustadt-Eberswald, in the neighbourhood of Berlin.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Copper - -	61·6	64 6	64·8	63·70	64·45	70·1	70 29	71·89	70·16
Zinc - -	35·3	33·7	32·8	33 55	32·44	29 9	29·26	27·63	27·45
Lead - -	2·9	1·4	2·0	0·25	2·86	- -	0·28	- -	0·20
Tin - -	0·2	0·2	0·4	2·50	0·25	- -	0·17	0·85	0·79
	100·0	99·9	100·0	100·00	100·0	- -	100·00	100·37	98·60

The mean proportion of the metals in yellow brass is 30 zinc to 70 copper.

Tombak, or Red Brass, in the cast state, is an alloy of copper and zinc, containing not more than 20 per cent. of the latter constituent. The following varieties are distinguished:—1, 2, 3. tombak for making gilt articles; 4. French tombak for sword-handles, &c.; 4. tombak of the Okar, near Goslar, in the Hartz; 5. yellow tombak of Paris for gilt ornaments; 6. tombak for the same purpose from a factory in Hanover; 8. chrysochalk; 9. red tombak from Paris; 10. red tombak of Vienna.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Copper -	82·0	82	82·3	80	85	85·3	86	90·0	92	97·8
Zinc - -	18·0	18	17·5	17	15	14·7	14	7·9	8	2·2
Lead - -	1·5	3	- -	- -	- -	- -	- -	1·6		
Tin - -	3·0	1	0.2	3	trace.					
	104·5	104	100·0	100	100	100 0	100	99·5	100	100·0

Pinchbeck is made of 2 parts copper and 1 yellow brass:
Prince's metal ... 3 ...... 1 *zinc.*
Mannheim gold (semilor), 28 copper, 12 yellow brass, 3 tin.

Cast white metal buttons are made of an alloy of 32 parts brass (yellow), 4 parts zinc, and 2 tin.

The specific gravity of brass is greater than the mean density of its constituents, varying from 7·82 to 8·73, according to the proportion of zinc to copper. Sheet brass varies from 8·52 to 8·62; brass wire from 8·49 to 8·73. Brass heated and quickly cooled becomes somewhat less dense. The specific gravity of sheet tombak (81·25 copper + 18·75 zinc) is 8·788; of tombak wire (87·5 copper + 12·5 zinc) has been found so great as 9·00.

Brass, Malleable. It is known that common brass containing from 27·4 to 31·8 per cent. of zinc, and from 71·9 to 65·8 per cent. of copper, is not malleable while hot, but that articles of it must be made by casting. As it would be of great advantage in many branches of industry to have an alloy of this kind that could be worked while hot, like malleable iron, the information that such an alloy exists must be welcome to artists.

By melting together 33 parts of copper, and 25 parts of zinc, there was a loss of three parts; thus making 60 per cent. copper, and 40 per cent. zinc. It differs from the English specimens by containing a larger proportion of zinc, and possesses, according to M. Machts, the precious property of malleability in a higher degree than the English specimens.

A piece of "yellow metal," similar in colour to this alloy, was found, on analysis, to contain 60·16 copper, and 39·71 zinc, which is the composition of malleable brass. It also showed great density or solidity.

An alloy was prepared by melting together 60 parts copper and 40 parts zinc, which had the following properties:—The colour was between that of brass and tombak, it had a strong metallic lustre, a fine, close grained fracture, and great solidity (density). Its specific gravity at the temperature of 10° Cent. was 8·44; by calculation it ought only to have been 8·08; thus showing that in the formation of the alloy a condensation must have taken place. Calculation shows that the alloy may be considered as a determinate chemical combination, for the results of the analysis very nearly accord with the assumption that it may be considered as composed of 3 atoms by weight of copper, and 2 atoms by weight of zinc ($3\ Cu + 2\ Zn$). The hardness of the alloy is the same as that of fluor spar; it can be scratched by apatite (glass), consequently its hardness is =4. The alloy is harder than copper, very tough, and is, in a properly managed fire, malleable; so much so that a key was forged out of a cast rod.

These important properties of this alloy warrant an expectation of its application to many purposes in the arts, and it would appear that they depend on its definite chemical proportions. Agreeably to the directions of M. Feyerabind, care must be taken in melting together the metals, not to permit too great a loss of zinc to take place, lest the proportions between the metals should be altered, which might not be without effect on the important properties of the alloy. With this view, it might be advantageous in practice, in place of zinc, to add, in melting, a proportionate mixture of brass to the proper proportions of copper. An alloy prepared in this way gave, on analysis, 61·44 copper, and 38·15 zinc. It is very probable that malleable brass will hereafter, in many cases, be made use of instead of the higher priced copper.

BRAZING. (*Braser*, Fr.; *Messing-lothung*, Germ.) The soldering together of edges of iron, copper, brass, &c., with an alloy consisting of brass and zinc, sometimes with a little tin or silver. The surfaces to be thus united must be filed perfectly bright, and not be soiled with the fingers or in any other way. The granular or nearly pulverulent alloy is usually wetted with a paste of ground borax and water, applied in this state, dried, and then exposed carefully to bright ignition at a clear forge fire. Some workmen enclose the part to be soldered in a clay lute, but others prefer leaving it uncovered, that they may see when the solder has flowed freely, and entered into all the seams.

BRAZIL-WOOD. (*Bois de Fernambouc*, Fr.; *Brasilienholz*, Germ.) This dye-wood derives its name from the part of America whence it was first imported. It has also the names Fernambuca, wood of Saint Martha, and of Sapan, according to the places which produce it. Linnæus distinguishes the tree which furnishes the Brazil-wood by the name of *Cæsalpinia crista*. It commonly grows in dry places among rocks. Its trunk is very large, crooked, and full of knots. It is very hard, susceptible of a fine polish, and sinks in water. It is pale when newly cleft, but becomes red on exposure to the air.

It has different shades of red and orange. Its goodness is determined particularly by its density. When chewed, a saccharine taste is perceived. It may be distinguished from red saunders wood, as the latter does not yield its color to water.

Boiling water extracts the whole coloring matter of Brazil-wood. If the ebullition be long enough continued, it assumes a fine red color. The residuum appears black. In this case, an alkali may still extract much coloring matter. The solution in alcohol or ammonia is still deeper than the preceding.

The decoction of Brazil-wood, called juice of Brazil, is observed to be less fit for dyeing when recent, than when old or even fermented. By age, it takes a yellowish-red color. For making this decoction, Hellot recommends to use the hardest water; but it should be remarked, that this water deepens the color in proportion to the earthy salts which it contains. After boiling this wood reduced to chips, or, what is preferable, to powder, for three hours, this first decoction is poured into a cask. Fresh water is poured on the wood, which is then made to boil for three hours, and mixed with the former. When Brazil-wood is employed in a dyeing bath, it is proper to enclose it in a thin linen bag, as well as all the dye-woods in general.

Wool immersed in the juice of Brazil takes but a feeble tint, which is speedily destroyed. It must receive some preparations.

The wool is to be boiled in a solution of alum, to which a fourth or even less of tartar is added, for a larger proportion of tartar would make the color yellowish. The wool is kept impregnated with it for at least eight days, in a cool place. After this, it is dyed in the Brazil juice with a slight boiling. But the first coloring particles that are deposited, afford a less beautiful color; hence it is proper to pass a coarser stuff previously through the bath. In this manner a lively red is procured, which resists pretty well the action of the air.

Brazil-wood is made use of for dyeing silk what is called false crimson, to distinguish it from the crimson made by means of cochineal, which is much more permanent.

The silk should be boiled at the rate of 20 parts of soap per cent., and then alumed. The aluming need not be so strong as for the fine crimson. The silk is refreshed at the river, and passed through a bath more or less charged with Brazil juice, according to the shade to be given. When water free from earthy salts is employed, the color is too red to imitate crimson; this quality is given it by passing the silk through a slight alkaline solution, or by adding a little alkali to the bath. It might, indeed, be washed in a hard water till it had taken the desired shade.

To make deeper false crimsons of a dark red, juice of logwood is put into the Brazil bath after the silk has been impregnated with it. A little alkali may be added, according to the shade that is wanted.

To imitate poppy or flame color, an annotto ground is given to the silk, deeper even than when it is dyed with carthamus. It is washed, alumed, and dyed with juice of Brazil, to which a little soap water is usually added.

The coloring particles of Brazil-wood are easily affected, and made yellow by the action of acids.

They thus become permanent colors. But what distinguishes them from madder and kermes, and approximates them to cochineal, is their reappearing in their natural color, when they are thrown down in a state of combination with alumina, or with oxyde of tin. These two combinations seem to be the fittest for rendering them durable. It is requisite, therefore, to inquire what circumstances are best calculated to promote the formation of these combinations, according to the nature of the stuff.

The astringent principle, likewise, seems to contribute to the permanence of the coloring matter of Brazil-wood; but it deepens its hue, and can only be employed for light shades.

The coloring particles of Brazil-wood are very sensible to the action of alkalis which give them a purple hue; and there are several processes in which the alkalis, either fixed or volatile, are used for forming violets and purples. But the colors obtained by these methods, which may be easily varied according to the purpose, are perishable, and possess but a transient bloom. The alkalis appear not to injure the colors derived from madder, but they accelerate the destruction of most other colors.

In England and Holland the dye-woods are reduced to powder by means of mills erected for the purpose.

The bright fugitive red, called fancy red, is given to cotton by Nicaragua, or peachwood, a cheap kind of Brazil-wood.

The cotton being scoured and bleached, is boiled with sumach. It is then impregnated with a solution of tin (at 5° Baumé, according to Vitalis). It should now be washed slightly in a weak bath of the dyeing wood, and, lastly, worked in a somewhat stale infusion of the peach or Brazil wood. When the temperature of this is lukewarm, the dye is said to take better. Sometimes two successive immersions in the bath are given. It is now wrung out, aired, washed in water, and dried.

M. Vitalis says, that his solution of tin is prepared with two ounces of tin and a pound of aqua regia made with two parts of nitric acid at 24° Baumé, and three parts of muriatic acid at 22°.

For a rose color, the cotton is alumed as usual, and washed from the alum. It then gets the tin mordant, and is again washed. It is now turned through the dye-bath, an operation which is repeated if necessary.

For purple, a little alum is added to the Brazil bath.

1. For amaranth, the cotton is strongly galled, dried, and washed.

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2. It is passed through the black cask (tonne au noir,) see Black Dye, till it has taken a strong gray shade.
3. It receives a bath of lime-water.
4. Mordant of tin.
5. Dyeing in the Brazil-wood bath.
6. The two last operations are repeated.

Dingler has endeavored to separate the coloring matter of the different sorts of Brazil-wood, so as to obtain the same tint from the coarser as from the best Pernambuco. His process consists in treating the wood with hot water or steam, in concentrating the decoction so as to obtain 14 or 15 pounds of it from 4 pounds of wood, allowing it to cool, and pouring into it two pounds of skim milk; agitating, then boiling for a few minutes, and filtering. The dun coloring matters are precipitated by the coagulation of the caseous substance. For dyeing, the decoctions must be diluted with water; for printing they must be concentrated, so that 4 pounds of wood shall furnish only 5 or 6 pounds of decoction, and the liquor may be thickened in the ordinary way. These decoctions may be employed immediately, as by this treatment they have acquired the same property as they otherwise could get only by being long kept. A slight fermentation is said to improve the color of these decoctions; some ground wood is put into the decoction to favor this process.

As gelatine produces no precipitate with these decoctions, they consequently contain no tannin. Gall-nuts, however, sumach, the bark of birch or alder, render the color of Brazil-wood more durable, upon alumed linen and cotton goods, but the shade is a little darker.

In dyeing wool with Pernambuco, the temperature of the bath should never be above 150° Fahr., since higher heats impair the color.

According to Dingler and Kurrer, bright and fast scarlet reds may be obtained upon wool, by preparing a decoction of 50 pounds of Brazil-wood in three successive boils, and setting the decoction aside for 3 or 4 weeks in a cool place; 100 pounds of the wool are then alumed in a bath of 22 pounds of alum and 11 pounds of tartar, and afterwards rinsed in cold water. Meanwhile we fill two thirds with water, a copper containing 30 pails, and heated to the temperature of 150° or 160° F. We pour in 3 pailfuls of the decoction, heat to the same point again, and introduce 30 pounds of wool, which does not take a scarlet, but rather a crimson tint. This being removed, 2 pails of decoction are put in, and 30 pounds of wool, which becomes scarlet, but not so fine as at the third dip. If the dyer strengthens the color a little at the first dip, a little more at the second, and adds at the third and fourth the quantity of decoction merely necessary, he will obtain a uniform scarlet tint. With 50 pounds of Pernambuco 1000 pounds of wool may be dyed scarlet in this way, and with the deposites another 100 may be dyed of a tile color. An addition of weld renders the color faster but less brilliant.

Karkutsch says the dye may be improved by adding some ox-gall to the bath.

In dyeing cotton the tannin and gallic acid are two necessary mordants, and the color is particularly bright and durable, when the cloth has been prepared with the oily process of Turkey red.

It is said that stale urine heightens the color of the Brazil dye when the ground wood is moistened with it.

The quantity of Brazil or Nicaragua wood imported into the United Kingdom in 1835, was 6,242 tons, whereof 1,811 were exported; of Brazilietto 230 tons. The duty upon the first article is 5*s*. per ton.

BREAD (*Pain*, Fr.; *Brod*, Germ.) is the spongy mass produced by baking the leavened or fermented dough of wheat or rye flour, at a proper heat. It is the principal food of highly civilized nations. The skilful preparation of this indispensable article constitutes the art of the Baker. Dough baked without being fermented constitutes cakes or biscuits; but not bread strictly speaking.

Pliny informs us, that barley was the only species of corn at first used for food; and even after the method of reducing it to flour had been discovered, it was long before mankind learned the art of converting it into cakes.

Ovens were first invented in the East. Their construction was understood by the Jews, the Greeks, and the Asiatics, among whom baking was practised as a distinct profession. In this art, the Cappadocians, Lydians, and Phœnicians, are said to have particularly excelled. It was not till about 580 years after the foundation of Rome, that these artisans passed into Europe. The Roman armies, on their return from Macedonia, brought Grecian bakers with them into Italy. As these bakers had handmills beside their ovens, they still continued to be called *pistores*, from the ancient practice of bruising the corn in a mortar; and their bakehouses were denominated *pistoriæ*. In the time of Augustus there were no fewer than 329 public bakehouses in Rome; almost the whole of which were in the hands of Greeks, who long continued the only persons in that city acquainted with the art of baking good bread.

In nothing, perhaps, is the wise and cautious policy of the Roman government more remarkably displayed, than in the regulations which it imposed on the bakers within the city. To the foreign bakers who came to Rome with the army from Macedonia, a number of freedmen were associated, forming together an incorporation from which neither they nor their children could separate, and of which even those who married the daughters of bakers were obliged to become members. To this incorporation were intrusted all the mills, utensils, slaves, animals, every thing, in short, which belonged to the former bakehouses. In addition to these, they received considerable portions of land; and nothing was withheld, which could assist them in pursuing, to the best advantage, their highly prized labors and trade. The practice of condemning criminals and slaves, for petty offences, to work in the bakehouse, was still continued; and even the judges of Africa were bound to send thither, every five years, such persons as had incurred that kind of chastisement. The bakehouses were distributed throughout the fourteen divisions of the city, and no baker could pass from one into another without special permission. The public granaries were committed to their care; they paid nothing for the corn employed in baking bread that was to be given in largess to the citizens; and the price of the rest was regulated by the magistrates. No corn was given out of these granaries except for the bakehouses, and for the private use of the prince. The bakers had besides private granaries, in which they deposited the grain, which they had taken from the public granaries for immediate use; and if any of them happened to be convicted of having diverted any portion of the grain to another purpose, he was condemned to a ruinous fine of five hundred pounds weight of gold.

Most of these regulations were soon introduced among the Gauls; but it was long before they found their way into the more northern countries of Europe. Borrichius informs us that in Sweden and Norway, the only bread known, so late as the middle of the 16th century, was unleavened cakes kneaded by the women. At what period in our own history the art of baking became a separate profession, we have not been able to ascertain; but this profession is now common to all the countries in Europe, and the process of baking is also nearly the same.

The French, who particularly excel in the art of baking, have a great many different kinds of bread. Their *pain bis*, or brown bread, is the coarsest kind of all, and is made of coarse groats mixed with a portion of white flour. The *pain bis blanc*, is a kind of bread between white and brown, made of white flour and fine groats. The *pain blanc*, or white bread, is made of white flour, shaken through a sieve after the finest flour has been separated. The *pain mollet*, or soft bread, is made of the purest flour without any admixture. The *pain chaland*, or customers' bread, is a very white kind of bread, made of pounded paste. *Pain chapelé*, is a small kind of bread, with a well-beaten and very light paste, seasoned with butter or milk. This name is also given to a small bread, from which the thickest crust has been removed by a knife. *Pain cornu*, is a name given by the French bakers to a kind of bread made with four corners, and sometimes more. Of all the kinds of small bread, this has the strongest and firmest paste. *Pain à la reine*, queen's bread, *pain à la Sigovie*, *pain chapelé*, and *pain cornu*, are all small kinds of bread, differing only in the lightness or thickness of the paste. *Pain gruau* is a small very white bread made now in Paris, from the flour separated after a slight grinding from the best wheat. Such flour is in hard granular particles.

In this country we have fewer varieties of bread, and these differ chiefly in their degrees of purity. Our white or fine bread is made of the purest flour; our wheaten bread, of flour with a mixture of the finest bran; and our household bread, of the whole substance of the grain without the separation either of the fine flour or coarse bran. We have also symnel bread, manchet or roll bread, and French bread, which are all made of the purest flour from the finest wheat; the roll bread being improved by the addition of milk, and the French bread by the addition of eggs and butter. To these may be added gingerbread, a cake made of flour, with almonds, liquorice, aniseed, rose-water, and sugar or treacle; and mastlin bread, made of wheat and rye, or sometimes of wheat and barley. We have various kinds of small bread, having various names, according to their various forms. They are, in general, extremely light, and are sweetened with sugar, currants, and other palatable ingredients. In Scotland there is a cake called *short bread*, made from a pretty thick dough, enriched with butter, sweetened with sugar, and seasoned with orange peel, or other kinds of spices.

The process of making bread is nearly the same in all the countries of modern Europe; though the materials of which it is composed vary with the farinaceous productions of different climates and soils. The flour of wheat is most generally employed for this purpose, wherever that vegetable can be reared. This flour is composed of a small portion of mucilaginous saccharine matter, soluble in cold water, from which it may be separated by evaporation; of a great quantity of starch, which is scarcely soluble in cold water, but capable of combining with that fluid by means of heat; and an adhesive gray substance called gluten, insoluble in water, ardent spirit, oil, or ether, and resembling an animal substance in many of its properties. Flour kneaded with water, forms a tough and rather indigestible paste containing all the constituent parts which we have enumerated. Heat produces a considerable change on the glutinous part of this compound, and renders it more easy of mastication and digestion. Still, however, it continues heavy and tough, compared with bread which is raised by leaven or yeast. Leaven is nothing more than a piece of dough, kept in a warm place till it undergoes a process of fermentation; swelling, becoming spongy, or full of air bubbles, at length disengaging an acidulo-spirituous vapor, and contracting a sour taste. When this leaven is mingled in proper proportions with fresh-made dough, it makes it rise more readily and effectually than it would do alone, and gives it at the same time a greater degree of firmness. Upon the quality of the leaven employed, the quality of the bread materially depends.

The principal improvement which has been made on bread in modern times, is the substitution of yeast or barm in place of common leaven. This yeast is the viscid froth that rises to the surface of beer, in the first stage of its fermentation. When mixed with the dough, it makes it rise much more speedily and effectually than ordinary leaven, and the bread is of course much lighter, and freer from that sour and disagreeable taste which may often be perceived in bread raised with leaven, either because too much is mingled with the paste, or because it has been allowed to advance too far in the process of fermentation.

Bread properly raised and baked differs materially from unleavened cakes, not only in being less compact and heavy, and more agreeable to the taste, but in losing its tenacious and glutinous qualities, and thus becoming more salutary and digestible.

We possess several analyses of wheat flour. Ordinary wheat (*triticum hybernum mixed with triticum turgidum*) contains, according to the analyses made by Vauquelin of several species of wheat flour, the following substances:—

Species of Wheat.	Water.	Gluten.	Starch.	Sugar.	Gum.	Bran.	Total.	Water of dough
French wheat flour - -	10·0	10·96	71·49	4·72	3·32	-	100·49	50·3
Hard wheat of Odessa flour - - - - - -	12·0	14·55	56·50	8·48	4·90	2·3	98·73	51·2
Soft wheat of Odessa flour - - - - - -	10·0	12·00	62·00	7·56	5·80	1·2	98·42	54·8
Same sort of flour - -	8·0	12·10	70·84	4·90	4·60	-	100·41	37·4
Same sort of flour - -	12·0	7·30	72·00	5·42	3·30	-	100·02	37·2
Wheat of the French bakers - - - - -	10·0	10·20	72·80	4·20	2·80	-	100·00	40·6
Flour of the Paris hospitals (2d quality) -	8·0	10·30	71·20	4·80	3·60	-	97·90	37·8
Ditto (3d quality) - -	12·0	9·02	67·78	4·80	4·60	2·0	100·21	37·8

The following table of analyses merits also a place here.

Species of Flour.	Water.	Gluten.	Starch.	Sugar.	Gummigluten.	Albumen.	Bran.
Flour of the triticum spelta	1	22·	74·	5·50	1·	1·50	
Ditto triticum hybernum	1	24·	68·	5·0	1·	1·50	
Ditto common wheat -		12·5	74·5	12·	2·		
Ditto wheat and rye mixed (mastlin) - -	6	9·80	75·50	4·22	3·28	-	1·2

The first two of the above analyses were made by Vogel, the third by Proust, and the fourth by Vauquelin.

Analyses of the flour of some other corns.

Species of Flour.	Starch.	Mucilage.	Gluten.	Albumen.	Sugar.	Husk.	Hordein.
White oatmeal - - -	59·00	2·5	-	4·30	8·25	Of a fat oil, 2	
Barley meal - - - -	32·00	9·	3·	-	Of resin, 2	-	55

The first analysis is by Vogel, the second by Proust.

It deserves to be remarked, that the flour of Odessa contains a much greater quantity of sugar than the French flour. The substance indicated in the preceding table by the name of gluten, is the gluten of Beccaria; that is to say, a mixture of gluten and vegetable albumen. The gum of wheat is not quite identical with ordinary gum. It is a brown azotized substance, which, when treated by nitric acid, affords no mucic acid, but oxalic acid and the bitter principle of Welter. It contains besides superphosphate of lime.

The last column of the first table exhibits the quantity of water necessary to convert the flour into dough of the ordinary consistence, and it is usually proportional to the quantity of gluten. The hard wheat of Odessa forms an exception in this respect; the reason of the difference being that the starch contained in this flour is not as in ordinary flour in a fine powder, but in small transparent grains, which resemble pounded gum, and absorb less water than pulverulent starch.

The *triticum monococcon*, according to Zenneck, contains in its unsifted flour, 16·334 of gluten and vegetable albumen; 64·838 of starch; 11·347 of gum, sugar, and extractive; 7·481 of husks. The sifted flour affords 15·536 of gluten and vegetable albumen; 76·459 of starch; 7·198 of sugar, gum, and extractive; 0·807 of husky matter. It is difficult to conceive how such great quantities of gluten, albumen, and extractive matter could disappear in the sifting. The triticum spelta contains in 100 parts of the finest flour, 22·5 of a soft and humid gluten, mixed with vegetable albumen; 74 of starch, and 5·5 of sugar. Here we have an excess of 2 parts in the 100.

Wheat furnishes very little ashes by incineration, not more than 0·15 per cent. of the weight; containing superphosphates of soda, lime, and magnesia.

The object of baking is to combine the gluten and starch of the flour into a homogeneous substance, and to excite such a vinous fermentative action, by means of its saccharine matter, as shall disengage abundance of carbonic acid gas in it for making an agreeable, soft, succulent, spongy, and easily digestible bread. The two evils to be avoided in baking are hardness on the one hand, and pastiness on the other. Well-made bread is a chemical compound, in which the gluten and starch cannot be recognised or separated, as before, by a stream of water. When flour is kneaded into a dough, and spread into a cake, this cake, when baked, will be horny if it be thin, or if thick, will be tough and clammy; whence we see the value of that fermentative process, which generates thousands of little cells in the mass or crumb, each of them dry, yet tender and succulent, through the intimate combination of the moisture. By this constitution it becomes easily soluble in the juices of the stomach, or, in other words, light of digestion. It is moreover much less liable to turn sour than cakes made from unfermented dough.

Rye, which also forms a true spongy bread, though inferior to that of wheat, consists of similar ingredients; namely, 61·07 of starch; 9·48 of gluten; 3·28 of vegetable albumen; 3·28 of uncrystallizable sugar; 11·09 of gum; 6·38 of vegetable fibre; the loss upon the 100 parts amounted to 5·62, including an acid whose nature the analyst, M. Einhof, did not determine. Rye flour contains also several salts, principally the phosphates of lime and magnesia. This kind of grain forms a dark-colored bread reckoned very wholesome; comparatively little used in this country, but very much in France, Germany, and Belgium.

Dough fermented with the aid either of leaven or yeast, contains little or none of the saccharine matter of the flour, but in its stead a certain portion, nearly half its weight, of spirit, which imparts to it a vinous smell, and is volatilized in the oven; whence it might be condensed into a crude weak alcohol, on the plan of Mr. Hick's patent, were it worth while. But the increased complexity of the baking apparatus will probably prove an effectual obstacle to the commercial success of this project, upon which already upwards of £20,000 sterling have been squandered.

That the sugar of the flour is the true element of the fermentation preposterously called panary, which dough undergoes, and that the starch and gluten have nothing to do with it, may be proved by decisive experiments. The vinous fermentation continues till the whole sugar is decomposed, and no longer; when, if the process be not checked by the heat of baking, the acetous fermentation will supervene. Therefore, if a little sugar be added to a flour which contains little or none, its dough will become susceptible of fermenting, with extrication of gas, so as to make spongy succulent bread. But since this sponginess is produced solely by the extrication of gas, and its expansion in the heat of the oven, any substance capable of emitting gas, or of being converted into it under these circumstances, will answer the same purpose. Were a solution of bicarbonate of ammonia obtained by exposing the common sesqui-carbonate in powder for a day to the air, incorporated with the dough, in the subsequent firing it will be converted into vapor, and in its extrication render the bread very porous. Nay, if water highly impregnated with carbonic acid gas be used for kneading the dough, the resulting bread will be somewhat spongy. Could a light article of food be prepared in this way, then as the sugar would remain undecomposed, the bread would be so much the sweeter, and the more nourishing. How far a change propitious to digestion takes place in the constitution of the starch and gluten, during the fermentative action of the dough, has not been hitherto ascertained by precise experiments. Medical practitioners, who

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derive an enormous revenue from dyspepsia, should take some pains to investigate this subject.

Dr. Colquhoun, in his able essay upon the art of making bread, has shown that its texture, when prepared by a sudden formation and disengagement of elastic fluid generated within the oven, differs remarkably from that of a loaf which has been made after the preparatory fermentation with yeast. Bread which has been raised with the common carbonate of ammonia, as used by the pastry-cooks, is porous no doubt, but not spongy with vesicular spaces, like that made in the ordinary way. The former kind of bread never presents that air-cell stratification which is the boast of the Parisian baker, but which is almost unknown in London. I have found it, moreover, very difficult to expel by the oven the last portion of the ammonia, which gives both a tinge and a taste to the bread. I believe, however, that the bicarbonate would be nearly free from this objection, which operates so much against the sesqui-carbonate of the shops.

In opposition to Mr. Edlin's account of the excellent quality of bread made by impregnating dough with carbonic acid gas,* Dr. Colquhoun adduces Vogel's experiments, which show that such dough, when baked, after having been kept in a warm situation during the usual time, afforded nothing better than a hard cake, which had no resemblance to common bread. Vogel further states, as illustrative of the general necessity of providing a sufficient supply of disengaged elastic fluid within the dough, before baking it at all, that when he made various attempts to form a well-raised vesicular loaf within the oven, by mixing flour with carbonate of magnesia, or with zinc filings, and then kneading it into a paste by means of water, acidulated with sulphuric acid, he always met with complete failure and disappointment. Dr. Colquhoun performed a series of well-devised experiments on this subject, which fully confirmed Vogel's results, and prove that a proper spongy bread cannot be made by the agency of either carbonic acid water, or of mixtures of sesqui-carbonate of soda, and tartaric acid. The bread proved doughy and dense in every case, though less so with the latter mixture than the former. No loaf bread can, indeed, be well made by any of these two extemporaneous systems, because they are inconsistent with the thorough kneading of the dough. It is this process which renders dough at once elastic enough to expand when carbonic acid gas is generated within it, and cohesive enough to confine the gas when it is generated. The whole gas of the loaf is disengaged in its interior by a continuous fermentation, after all the processes of kneading have been finished; for the loaf, after being kneaded, weighed out, and shaped, is set aside till it expands gradually to double its bulk, before it is put into the oven. But when a dough containing sesqui-carbonate of soda is mixed with one containing muriatic acid, in due proportions to form the just dose of culinary salt, the gas escapes during the necessary incorporation of the two, and the bread formed from it is dense and hard. Dr. Whiting has, however, made this old chemical process the subject of a new patent for baking bread.

When the baker prepares his dough, he takes a portion of the water needed for the batch, having raised its temperature to from 70° to 100° F., dissolves a certain proportion of his salt in it, then adds the yeast, and a certain quantity of his flour. This mixture, called the *sponge*, is next covered up in the small kneading-trough, alongside of the large one, and let alone for *setting* in a warm situation. In about an hour, signs of vinous fermentation appear, by the swelling and heaving up of the sponge, in consequence of the generation of carbonic acid; and if it be of a semi-liquid consistence, large air bubbles will force their way to the surface, break, and disappear in rapid succession. But when the *sponge* has the consistence of thin *dough*, it confines the gas, becomes thereby equably and progressively inflated to double its original volume; when no longer capable of containing the pent-up air, it bursts and subsides. This process of rising and falling alternately might be carried on during twenty-four hours, but the baker has learned by experience to guard against allowing full scope to the fermentative principle. He generally interferes after the first, or at furthest after the second or third dropping of the sponge; for were he not to do so, the bread formed with such dough would be invariably found sour to the taste and the smell. Therefore he adds at this stage to the sponge the reserved proportions of flour, salt, and water, which are requisite to make the dough of the desired consistence and size; and next incorporates the whole together by a long and laborious course of kneading. When this operation has been continued till the fermenting and the fresh dough have been intimately blended, and till the glutinous matter of both is worked into such union and consistence that the mass becomes so tough and elastic as to receive the smart pressure of the hand without adhering to it, the kneading is suspended for some time. The dough is now abandoned to itself for a few hours, during which it continues in a state of active fermentation throughout its entire mass. Then it is subjected to a second but much less laborious kneading, in order to distribute the generated gas as evenly as possible among its parts, so that they may all partake equally of the vesicular structure. After this second kneading, the dough is weighed out into the portions suitable to the size of bread desired; which are of course shaped into the proper forms, and once more set aside in a warm situation. The continuance of the fermentation soon disengages a fresh quantity of carbonic acid gas, and expands the lumps to about double their pristine volume. These are now ready for the oven, and when they finally quit it in the baked state, are about twice the size they were when they went in. The generation of the due quantity of gas should be complete before the lumps are transferred to the oven; because whenever they encounter its heat, the process of fermentation is arrested; for it is only the previously existing air which gets expanded throughout every part of the loaf, swells out its volume, and gives it the *piled* and vesicular texture. Thus the well-baked loaf is composed of an infinite number of cellules filled with carbonic acid gas, and apparently lined with a glutinous membrane of a silky softness. It is this which gives the light, elastic, porous constitution to bread.

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* Treatise on the Art of Bread Making, p. 56

After suffering the fermentative process to exhaust itself in a mass of dough, and the dough to be brought into that state in which the addition of neither yeast, nor starch, nor gluten will produce any effect in restoring that action, if we mix in 4 per cent. of saccharine matter, of any kind, with a little yeast, the process of fermentation will immediately re-commence, and pursue a course as active and lengthened as at first, and cease about the same period.*

This experiment, taken in connexion with the facts formerly stated, proves that what was called panary fermentation, is nothing but the ancient and well-known process of the vinous fermentation of sugar, which generates alcohol. There seems to be but one objection to the adoption of this theory. After the loaf is baked, there is found in its composition nearly as much saccharine matter as existed in the flour before fermentation. M. Vogel states that in the baked bread there remains 3·6 parts of sugar, out of the 5 parts which it originally contained. Thus, in 100 parts of loaf bread prepared with wheaten flour, distilled water, and yeast without the admixture of any common salt, he found the following ingredients:—

Sugar - - -	3·6
Torrefied or gummy starch -	18·0
Starch - - -	53·5
Gluten, combined with a little starch,	20·75

Exclusive of carbonic acid, muriate of lime, phosphate of lime, &c.

It must be borne in mind that in every loaf the process of fermentation has been prematurely checked by the baker's oven, and therefore the saccharine constituent can never be wholly decomposed. It seems certain, also, that by the action of gluten upon the starch in the early stage of the firing, a quantity of sugar will be formed by the saccharine fermentation; which we have explained in treating of BEER.

Several masses of dough were prepared by Dr. Colquhoun in which pure wheat starch was mixed with common flour, in various proportions. In some of the lumps this starch had been gelatinized, with the *minimum* of hot water, before it was added to the flour. After introducing the usual dose of salt, the dough was thoroughly kneaded, set apart for the proper period, allowed to ferment in the accustomed way, and then baked in the oven. In outward appearance, increase of bulk, and vesicular texture, none of them differed materially from a common loaf, baked along with them for the sake of comparison; except that when the starch considerably exceeded the proportion of flour in the lump, the loaf, though whiter, had not risen so well, being somewhat less vesicular. But, on tasting the bread of each loaf, those which contained most gelatinized starch were unexpectedly found to be the sweetest. The other loaves, into which smaller quantities of the gelatinized starch had been introduced, or only some dry starch, had no sweetish taste whatever to distinguish them from ordinary bread. These facts seem to establish the conclusion, that the presence of gelatinous starch in bread put into the oven, is a means of forming a certain portion of saccharine matter within the loaf, during the baking process. Now it is more than probable that gelatinized starch does exist, more or less, in all loaves which have been fermented by our usual methods, and hence a certain quantity of sugar will necessarily be generated at its expense, by the action of heat. Thus the difficulty started by M. Vogel is sufficiently solved; and there remains no doubt that, in the saccharine principle of flour, the fermentation has its origin and end, while dough is under fermentation.

The source of the sourness which supervenes in bread, under careless or unskilful hands, had been formerly ascribed to each of all the constituents of flour; to its gluten, its starch, and its sugar; but erroneously, as we now see: for it is merely the result of the second fermentation which always succeeds the vinous, when pushed improperly too far. It has been universally taken for granted by authors, that the acid thus generated in dough is the acetic. But there appear good grounds to believe that it is frequently a less volatile acid, probably the lactic, particularly when the process has been tardy, from the imperfection of the yeast or the bad quality of the flour. The experiments of Vogel, Braconnot, and others, prove that the latter acid is generated very readily, and in considerable quantity during the spontaneous decomposition of a great many vegetable substances, when in a state of humidity. The presence of lactic acid would account for the curious fact, that the acidity of unbaked dough is much more perceptible to the taste than to the smell; while the sourness of the same piece of bread, after coming out of the oven, is, on the contrary, much more obvious to the olfactory organs than to the palate. But this is exactly what ought to happen, if the lactic acid contributes, in conjunction with the acetic, to produce the acescence of the dough. At the ordinary temperature of a bakehouse, the former acid, though very perceptible in the mouth, is not distinguishable by the nostrils; but as it is easily decomposed by heat, no sooner is it exposed to the high temperature of the oven, than it is resolved, in a great measure, into acetic acid,[*] and thus becomes more manifest to the sense of smell, and less to that of taste. This theory seems to explain satisfactorily all the phenomena accompanying the progress of fermentation in baker's dough, and also some of its results in the process of baking which do not easily admit of any other solution.

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* Dr. Colquhoun, in Annals of Philosophy for 1826, vol. xii. p. 171

There are extremely simple and effectual methods for enabling the baker to adopt measures either to prevent or correct the evil of acescence, and these are to neutralize the acid by the due exhibition of an alkali, such as soda; or an alkaline earth, such as magnesia or chalk. And it affords a striking proof of how much the artisan has been accustomed to plod, uninquiring and uninformed, over the same ground, that a remedy so safe and so economical, should remain at this day unthought of and unemployed by most of the manufacturers of bread in the United Kingdom. The introduction of a small portion of carbonate of soda will rectify any occasional error in the result of the so called panary fermentation, and will, in fact, restore the dough to its pristine sweetness. The quantity of acetate of soda, which will be thus present in the bread, will be altogether inconsiderable; and as it has no disagreeable taste, and is merely aperient to the bowels in a very mild degree, it can form no objection in the eye of the public police. The restoration of dough thus tainted with acid, and its conversion into pleasant and wholesome bread, has been sufficiently verified by experiment. But, according to Mr. Edmund Davy, carbonate of magnesia may be used with still greater advantage, as during the slow action of the acid upon it, the carbonic acid evolved serves to open up and lighten bread which would otherwise be dense and doughy from the indifferent quality of the flour. Here, however, the dangerous temptation lies with a sordid baker to use cheap or damaged flour, and to rectify the bread made of it by chemical agents, innocent in themselves, but injurious as masks of a bad raw material. When sour yeast must be used, as sometimes happens with the country bakers, or in private houses at a distance from beer breweries, there can be no harm, but, on the contrary, much propriety, in correcting its acidity, by the addition of as much carbonate of soda to it as will effect its neutralization, but nothing more. When sour yeast has been thus corrected, it has been found, in practice, to possess its fermentative power unimpaired, and to be equally efficacious with fresh formed yeast, in making good palatable loaves.

We have seen that, in baking, about one fourth of the starch is converted into a matter possessing the properties of *British gum* (see STARCH), and also that the gluten, though not decomposed, has its particles disunited, and is not so tough and adhesive as it is in the flour. This principle is also, as we have said, useful in cementing all the particles of the dough into a tenacious mass, capable of confining the elastic fluid generated by the vinous fermentation of the sugar. Starch is the main constituent, the basis of nourishment in bread, as well as in all farinaceous articles of food. The albumen also of the wheat, being coagulated by the heat of the oven, contributes to the setting of the bread into a consistent elastic body.

In the mills in the neighborhood of London, no less than seven distinct sorts of flour are ground out of one quantity of wheat. These are for one quarter—

Fine flour - - - - - -	5 bushels	3 pecks.
Seconds - - - - - - - -	0	2
Fine middlings - - - - - -	0	1
Coarse middlings - - -	0	0·5
Bran - - - - - - - - -	3	0
Twenty-penny - - - - - -	3	0
Pollard - - - - - - -	2	
	11	2·5

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[*] Berzelius.

So that we have nearly a double bulk of flour, or 14 bushels and 2½ pecks from 8 bushels of wheat. In the sifting of the flour through the bolter, there is a fine white angular meal obtained called sharps, which forms the central part of the grain. It is consumed partly by the fine biscuit bakers. The bakers of this country were formerly bound by law to bake three kinds of bread, the *wheaten*, *standard wheaten*, and the *household;* marked respectively with a W, S W, and H, and if they omitted to make these marks on their bread they were liable to a penalty. The size of the loaves were usually peck, half-peck, quartern, and half-quartern; the weights of which, within 48 hours of their being baked, should have been respectively 17 lbs. 6 oz.; 8 lbs. 11 oz.; 4 lbs. 5 oz. 8 dr.; and 4 lbs. 2 oz. 14 dr. In general they weigh about one seventh more before they enter the oven, or they lose one seventh of their weight in baking. The French bread loses fully one sixth in the oven, owing chiefly to its more oblong thin shape, as compared to the cubical shape of the English bread. But this loss of weight is very variable, being dependant upon the quality of the wheaten flour, and the circumstances of baking. The present law in England defines the quartern loaf at 4 lbs., and subjects the baker to a penalty if the bread be one ounce lighter than the standard. Hence it leaves the baker, in self-defence, to leave it in rather a damp and doughy state. But there is much light bread sold in London. I have met with quartern loaves of 3 lbs. 10 oz. A sack of flour weighing 280 lbs. was presumed by the framers of our former parliamentary acts, for the assize of bread, to be capable of being baked into 80 loaves. If this proportion had been correct, one fifth part of our quartern loaf must consist of water and salt, and four fifths of flour. But in general, of good wheaten flour, three parts will take up one part of water; so that the sack of flour should have turned out, and actually did turn out, more than 80 loaves. At present with 4 lb. bread it may well yield 92 loaves.

The following statement of the system of baking at Paris, I received in 1835 from a very competent judge of the business.

1,000 kilogrammes of wheat=5 quarters English, cost 200 fr., and yield 800 kilos. of flour of the best white quality, equivalent to $5\frac{1}{10}$ sacks French. Hence the sack of flour costs 40 francs at the mill, and including the carriage to Paris, it costs 45 or 46 francs.

The profit of the flour dealer is about 3½ francs, and the sale price becomes from 43 to 50 francs.

Bread manufactured from the above.

	£	s.	d.		£	s.	d.
One day's work of an ordinary baker, who makes four batches in a day, consists of 3 sacks at 50 francs, or 2*l.* sterling each					6	0	0
Salt 2¾ lbs. at 2*d.* per lb. - - - - - - - - -					0	0	5½
Yeast or leaven 3 lbs. at 5*d.* - - - - - - -					0	1	3
Total cost of materials - - - - - - - -					6	1	8½
Expenses of Baking.							
Three workmen at different rates of wages, 15 francs - -	0	12	0				
Fire-wood 0, as the charcoal produced pays for it - - -							
General expenses, such as rent, taxes, interest of capital, &c.	0	12	0				
	1	4	0	=	1	4	0
					7	5	8½
For this sum 315 loaves are made, being 105 for every sack of flour weighing 156·66 kilos. or 344⅔ lbs. avoird. One loaf contains therefore $\frac{344\cdot66}{105}=3\cdot282$ lbs., and as 100 lbs. of flour in Parisian baking are reckoned to produce 127 lbs. of bread, each loaf will weigh 4·168 lbs., avoird., and will cost 7*l.* 5*s.* 8½*d.* divided by 315 = 5½*d.* very nearly. The value of 315 loaves at the sale price of 6*d.* will be - - - - - - - - -					7	17	5
Upon this day's work the clear profit is therefore - -					0	11	6½

A new baking establishment has been recently formed at the Royal Clarence Victualling Establishment at Weevil, near Portsmouth, upon a scale of magnitude nearly sufficient to supply the whole royal navy with biscuits, and that of a very superior description. The following account of it is taken from the United Service Journal. "It having been discovered that the flour supplied to government by contract, had in many instances been most shamefully adulterated, the corn is ground at mills comprised within the establishment, by which means the introduction of improper ingredients is prevented, and precisely the proportion of bran which is requisite in the composition of good sea-biscuit is retained, and no more. The flour-mill is furnished with ten pairs of stones, by which 40 bushels of flour may be ground and dressed ready for baking, in an hour. The baking establishment consists of 9 ovens, each 13 feet long by 11 feet wide, and 17½ inches in height. These are each heated by separate furnaces, so constructed that a blast of hot air and fire sweeps through them, and gives to the interior the requisite dose of heat in an incredible short space of time. The first operation in making the biscuits consists in mixing the flour, or rather meal and water; 13 gallons of water are first introduced into a trough, and then a sack of the meal, weighing 280 lbs. When the whole has been poured in by a channel communicating with an upper room, a bell rings, and the trough is closed. An apparatus consisting of two sets of what are called knives, each set ten in number, are then made to revolve amongst the flour and water by means of machinery. This mixing operation lasts one minute and a half, during which time the double set of knives or stirrers makes twenty-six revolutions. The next process is to cast the lumps of dough under what are called the breaking-rollers,—huge cylinders of iron, weighing 14 cwt. each, and moved horizontally by the machinery along stout tables. The dough is thus formed into large rude masses 6 feet long by 3 feet broad, and several inches thick. At this stage of the business, the kneading is still very imperfect, and traces of dry flour may still be detected. These great masses of dough are now drawn out, and cut into a number of smaller masses about a foot and a half long by a foot wide, and again thrust under the rollers, which is repeated until the mixture is so complete that not the slightest trace of any inequality is discoverable in any part of the mass. It should have been stated that two workmen stand one at each side of the rollers, and as the dough is flattened out they fold it up, or double one part upon another, so that the roller at its next passage squeezes these parts together, and forces them to mix. The dough is next cut into small portions, and being placed upon large flat boards, is, by the agency of machinery, conveyed from the centre to the extremity of the baking-room. Here it is received by a workman, who places it under what is called the sheet roller, but which, for size, color, and thickness, more nearly resembles a blanket. The kneading is thus complete, and the dough only requires to be cut into biscuits before it is committed to the oven. The cutting is effected by what is called the cutting-plate, consisting of a net-work of 52 sharp-edged hexagonal frames, each as large as a biscuit. This frame is moved slowly up and down by machinery, and the workman, watching his opportunity, slides under it the above-described blanket of dough, which is about the size of a leaf of a dining-table; and the cutting-frame in its descent indents the sheet, but does not actually cut it through, but leaves sufficient substance to enable the workman at the mouth of the oven to jerk the whole mass of biscuits unbroken into it. The dough is prevented sticking to the cutting-frame by the following ingenious device: between each of the cutter-frames is a small flat open frame, moveable up and down, and loaded with an iron ball, weighing several ounces. When the great frame comes down upon the dough, and cuts out 52 biscuits, each of these minor frames yields to the pressure, and is raised up; but as soon as the great frame rises, the weight of the balls, acting upon the little frames, thrusts the whole blanket off, and allows the workmen to pull it out. One quarter of an hour is sufficient to bake the biscuit, which is afterwards placed for three days in a drying room, heated to 85° or 90°, which completes the process." The following statement of the performance of the machinery is taken from actual experiment; in 116 days, during 68 of which the work was continued for only 7½ hours; and during 48, for only 5¾ hours each day, in all 769 working hours, equal to 77 days of 10 hours each; the following quantity of biscuit was baked in the 9 ovens, viz.: 12,307 cwt. = 1,378,400 lbs. The wages of the men employed in baking this quantity amounted to 273*l.* 10*s.* 9½*d.*; if it had been made by hand, the wages would have been 933*l.* 9*s.* 10*d.*; saving in the wages of labor, 659*l.* 7*s.* 0½*d.* In this, is not included any part of the interest of the sum laid out upon the machine, or expended in keeping it in order. But in a very few years, at such an immense rate of saving, the cost of the engine and other machinery will be repaid. This admirable apparatus is the invention of T. T. Grant, Esq., storekeeper of the Royal Clarence Victualling Establishment, who, we believe, has been properly rewarded, by a grant of 2,000*l.* from government.

The labor of incorporating the ingredients of bread, viz., flour, water, and salt, or kneading dough, is so great as to have led to the contrivance of various mechanical modes of producing the same effect. One of the most ingenious is that for which a patent was obtained in August, 1830, by Mr. Edwin Clayton. It consists of a rotatory kneading trough, or rather barrel, mounted in bearings with a hollow axle, and of an interior frame of cast iron made to revolve by a solid axle which passes through the hollow one; in the frame there are cutters diagonally placed for kneading the dough. The revolving frame and its barrel are made to turn in contrary directions, so as greatly to save time and equalise the operation. This double action represents kneading by the two hands, in which the dough is inverted from time to time, torn asunder, and reunited in every different form. The mechanism will be readily understood from the following description

Fig. 190 exhibits a front elevation of a rotatory kneading trough, constructed according to improvements specified by the patentee, the barrel being shown in section *a* is the

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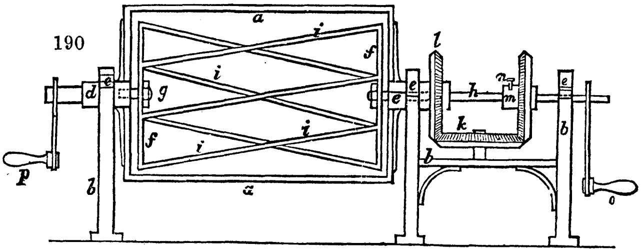

barrel, into which the several ingredients, consisting of flour, water, and yeast, are put, which barrel is mounted in the frame-work *b*, with hollow axles *c* and *d*, which hollow axles turn in suitable bearings at *e*; *f* is the revolving frame which is mounted in the interior of the barrel *a*, by axles *g* and *h*. The ends of this revolving frame are fastened, or braced together by means of the oblique cutters or braces *i*, which act upon the dough when the machine is put in motion, and thus cause the operation of kneading.

Either the barrel may be made to revolve without the rotatory frame, or the rotatory frame without the barrel, or both may be made to revolve together, but in opposite ways. These several motions may be obtained by means of the gear-work, shown at *k*, *l*, and *m*, as will be presently described.

If it be desired to have the revolving motion of the barrel and rotatory frame together, but in contrary directions, that motion may be obtained by fastening the hollow axle of the wheel *m*, by means of a screw *n*, to the axle *h*, of the rotatory frame *f*, tight, so as they will revolve together, the other wheels *k* and *l* being used for the purpose of reversing the motion of the barrel. It will then be found that by turning the handle *o*, the two motions will be obtained.

If it be desired to put the rotatory frame *f*, only, into motion, that action will be obtained by loosening the screw *n*, upon the axle of the wheel *m*, when it will be found that the axle *h* will be made to revolve freely by means of the winch *o*, without giving motion to the wheels *k*, *l*, and *m*, and thus the barrel will remain stationary. If the rotatory action of the barrel be wanted, it will be obtained by turning the handle *p*, at the reverse end of the machine, which, although it puts the gear at the opposite end of the barrel into motion, yet as the hollow axle of the wheel *m* is not fastened to the axle *h*, by the screw *n*, these wheels will revolve without carrying round the frame *f*.

M. Kuhlmann, Professor of Chemistry at Lille, having been called upon several times by the courts of justice to examine by chemical processes bread suspected of containing substances injurious to health, collected some interesting facts upon the subject, which were published under the direction of the central council of salubrity of the department *du Nord*.

For some time public attention had been drawn to an odious fraud committed by a great many bakers in the north of France and in Belgium—the introduction of a certain quantity of sulphate of copper into their bread. When the flour was made from bad grain this adulteration was very generally practised, as was proved by many convictions and confessions of the guilty persons. When the dough does not rise well in the fermentation (*le pain pousse plat*), this inconvenience was found to be obviated by the addition of blue vitriol, which was supposed also to cause the flour to retain more water. The quantity of blue water added is extremely small, and it is never done in presence of strangers, because it is reckoned a valuable secret. It occasions no economy of yeast, but rather the reverse. In a litre (about a quart) of water, an ounce of sulphate of copper is dissolved; and of this solution a wine-glass full is mixed with the water necessary for 50 quartern or 4 pound loaves.

M. Kuhlmann justly observes, that there can be no safety whatever to the public when such a practice is permitted, because ignorance and avarice are always apt to increase the quantity of the poisonous water. In analyses made by him and his colleagues, portions of bread were several times found so impregnated with the above salt that they had acquired a blue color, and presented occasionally even small crystals of the sulphate. By acting on the poisoned bread with distilled water, and testing the water with ferro-cyanate (prussiate) of potash, the reddish brown precipitate or tint characteristic of copper will appear even with small quantities. Should the noxious impregnation be still more minute, the bread should be treated with a very dilute nitric acid, either directly or after incineration in a platinum capsule, and the solution, when concentrated by evaporation, should be tested by the ferro-cyanate of potash. In this way, a one seventy thousandth part of sulphate of copper may be detected.

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M. Kuhlmann deduces, from a series of experiments on baking with various small quantities of sulphate of copper, that this salt exercises an extremely energetic action upon the fermentation and rising of the dough, even when not above one seventy thousandth part of the weight of the bread is employed; or one grain of sulphate for ten pounds of bread. The proportion of the salt which makes the bread rise best is one twenty thousandth, or one grain in three pounds of bread. If much more of the sulphate be added, the bread becomes moist, less white, and acquires a peculiar disagreeable smell like that of leaven. The increase of weight by increased moisture may amount to one sixteenth without the bread appearing softer, in consequence of the solidifying quality of the copper; for the acid does not seem to have any influence; as neither sulphate of soda, sulphate of iron, nor sulphuric acid have any analogous power. Alum operates like blue vitriol on bread, but larger quantities of it are required. It *keeps water*, and *raises well*, to use the bakers' terms.

When alum is present in bread it may be detected by treating the bread with distilled water, filtering the water first through calico, and next through filtering paper, till it becomes clear; then dividing it into two portions, and into the one pouring a few drops of nitrate or muriate of barytes, and into the other a few drops of water of ammonia. In the former a heavy white precipitate indicating sulphuric acid will appear, and in the latter a light precipitate of alumina, redissoluble by a few drops of solution of caustic potash.

When chalk or Paris plaster is used to sophisticate flour, they may be best detected by incinerating the bread made of it, and examining the ashes with nitric acid, which will dissolve the chalk with effervescence, and the Paris plaster without. In both cases the calcareous matter may be demonstrated in the solution, by oxalic acid, or better by oxalate of ammonia.

In baking puff-paste the dough is first kneaded along with a certain quantity of butter, then rolled out into a thin layer, which is coated over with butter, and folded face-wise many times together, the upper and under surfaces being made to correspond. This stratified mass is again rolled out into a thin layer, its surface is besmeared with butter, and then it is folded face-wise as before. When this process is repeated ten or a dozen times, the dough will consist of many hundred parallel laminæ, with butter interposed between each pair of plates. When a moderately thick mass of this is put into the oven, the elastic vapor disengaged from the water and the butter, diffuses itself between each of the thin laminæ, and causes them to swell into what is properly called puff-paste, being an assemblage of thin membranes, each dense in itself, but more or less distinct from the other, and therefore forming apparently, but not really, light bread.

One of the most curious branches of the baker's craft is the manufacture of gingerbread, which contains such a proportion of molasses, that it cannot be fermented by means of yeast. Its ingredients are flour, molasses or treacle, butter, common potashes, and alum. After the butter is melted, and the potashes and alum are dissolved in a little hot water, these three ingredients, along with the treacle, are poured among the flour, which is to form the body of the bread. The whole is then incorporated by mixture and kneading into a stiff dough. Of these five constituents the alum is thought to be the least essential, although it makes the bread lighter and crisper, and renders the process more rapid; for gingerbread dough requires to stand over several days, sometimes 8 or 10, before it acquires that state of porosity which qualifies it for the oven. The action of the treacle and alum on the potashes in evolving carbonic acid, seems to be the gasefying principle of gingerbread; for if the carbonate of potash is withheld from the mixture, the bread, when baked, resembles in hardness a piece of wood.

Treacle is always acidulous. Carbonate of magnesia and soda may be used as substitutes for the potashes. Dr. Colquhoun has found that carbonate of magnesia and tartaric acid may replace the potashes and the alum with great advantage, affording a gingerbread fully more agreeable to the taste, and much more wholesome than the common kind, which contains a notable quantity of potashes. His proportions are one pound of flour, a quarter of an ounce of carbonate of magnesia, and one eighth of an ounce of tartaric acid; in addition to the treacle, butter, and aromatics, as at present used. The acid and alkaline earth must be well diffused through the whole dough. The magnesia should, in fact, be first of all mixed with the flour. Pour the melted butter, the treacle, and the acid dissolved in a little water all at once among the flour, and knead into a consistent dough, which being set aside for half an hour or an hour will be ready for the oven, and should never be kept unbaked more than 2 or 3 hours. The following more complete recipe is given by Dr. Colquhoun, for making thin gingerbread cakes:—

Flour	1 lb.
Treacle	0½
Raw sugar	0¼

Butter	2 oz.
Carbon. magnesia	0¼
Tartaric acid	0⅛
Ginger	0⅛
Cinnamon	0⅛
Nutmeg	1

This compound has rather more butter than common thin gingerbread.

I shall here insert a passage from my Dictionary of Chemistry, as published in 1821; as it may prove interesting to many of my present readers.

"Under *Process of Baking*, in the Supplement to the Encyclopedia Britannica, we have the following statement:—'An ounce of alum is then dissolved over the fire in a tin pot, and the solution poured into a large tub, called by the bakers the seasoning-tub. Four pounds and a half of salt are likewise put into the tub, and a pailful of hot water.'—*Foot note on this passage.*—'In London, where the goodness of bread is estimated entirely by its whiteness, it is usual with those bakers who employ flour of an inferior quality, to add as much alum as common salt to the dough; or, in other words, the quantity of salt added is diminished one half, and the deficiency supplied by an equal weight of alum. This improves the look of the bread very much, rendering it much whiter and firmer.'"

In a passage which we shall presently quote, our author represents the bakers of London in a conspiracy to supply the citizens with bad bread. We may hence infer that the full allowance he assigns of 2¼ pounds of alum for every 2¼ pounds of salt, will be adopted in converting the sack of flour into loaves. But as a sack of flour weighs 280 pounds, and furnishes on an average 80 quartern loaves, we have 2¼ pounds divided by 80, or $\frac{15750 \text{ grains}}{80} = 197$ grains, for the quantity present, by this writer in a London quartern loaf. Yet in the very same page (39th of vol. ii.) we have the following passage: "Alum is not added by all bakers. The writer of this article has been assured by several bakers of respectability, both in Edinburgh and Glasgow, on whose testimony he relies, and who made excellent bread, that they never employed any alum. The reason for adding it given by the London bakers is, that it renders the bread whiter, and enables them to separate readily the loaves from each other. This addition has been alleged by medical men, and is considered by the community at large, as injurious to the health, by occasioning constipation. But if we consider the small quantity of this salt added by the baker, not quite 5½ grains to a quartern loaf, we will not readily admit these allegations. Suppose an individual to eat the seventh part of a quartern loaf a day, he would only swallow eight tenths of a grain of alum, or, in reality, not quite so much as half a grain; for one half of this salt consists of water. It seems absurd to suppose that half a grain of alum, swallowed at different times during the course of a day, should occasion constipation." Is it not more absurd to state 2¼ pounds or 36 ounces, as the alum adulteration of a sack of flour by the London bakers, and within a few periods to reduce the adulteration to one ounce?

That this voluntary abstraction of $\frac{35}{36}$ of the alum, and substitution of superior and more expensive flour, is not expected by him from the London bakers, is sufficiently evident from the following story. It would appear that one of his friends had invented a new yeast for fermenting dough, by mixing a quart of beer barm with a paste made of ten pounds of flour and two gallons of boiling water, and keeping this mixture warm for six or eight hours.

"Yeast made in this way," says he, "answers the purposes of the baker much better than brewers' yeast, because it is clearer, and free from the hop mixture which sometimes injures the yeast of the brewer. Some years ago the bakers of London, sensible of the superiority of this artificial yeast, invited a company of manufacturers from Glasgow to establish a manufactory of it in London, and promised to use no other. About 5,000*l.* accordingly was laid out on buildings and materials, and the manufactory was begun on a considerable scale. The ale-brewers, finding their yeast, for which they had drawn a good price, lie heavy on their hands, invited *all* the journeymen bakers to their cellars, gave them their fill of ale, and promised to regale them in that manner every day, provided they would force their masters to take all their yeast from the ale-brewers. The journeymen accordingly declared, in a body, that they would work no more for their masters unless they gave up taking any more yeast from the manufactory. The masters were obliged to comply; the new manufactory was stopped, and the inhabitants of London were obliged to continue to eat worse bread, because it was the interest of the ale-brewers to sell the yeast. Such is the influence of journeymen bakers in the metropolis of England!"

This doleful diatribe seems rather extravagant; for surely beer yeast can derive nothing noxious to a porter drinking people, from a slight impregnation of hops; while it must form probably a more energetic ferment than the fermented paste of the new company, which at any rate could be prepared in six or eight hours by any baker who found it to answer his purpose of making a pleasant eating bread. But it is a very serious thing for a lady or gentleman of sedentary habits, or infirm constitution, to have their digestive process daily vitiated by damaged flour, whitened with 197 grains of alum per quartern loaf. Acidity of stomach, indigestion, flatulence, headaches, palpitation, costiveness, and urinary calculi may be the probable consequences of the habitual introduction of so much acidulous and acescent matter.

I have made many experiments upon bread, and have found the proportion of alum very variable. Its quantity seems to be proportional to the badness of the flour; and hence when the best flour is used no alum need be introduced. That alum is not necessary for giving bread its utmost beauty, sponginess, and agreeableness of taste, is undoubted; since the bread baked at a very extensive establishment in Glasgow, in which about 20 tons of flour were regularly converted into loaves in the course of a week, united every quality of appearance with an absolute freedom from that acido-astringent drug. Six pounds of salt were used for every sack of flour; which, from its good quality, generally afforded 83 or 84 quartern loaves of the legal weight of four pounds five ounces and a half each. The loaves lost nine ounces in the oven.

Every baker ought to be able to analyze his flour. He may proceed as follows:—A ductile paste is to be made with a pound of the flour and a sufficient quantity of water, and left at rest for an hour; then having tied across a bowl a piece of silken sieve-stuff, a little below the surface of the water in the bowl, the paste is to be laid upon the sieve on a level with the water, and kneaded tenderly with the hand, so as merely to wash the starchy particles out of it. This portion of the flour gets immediately diffused through the water, some of the other constituents dissolve, and the gluten alone remains upon the filter. The water must be several times renewed till it ceases to become milky. The last washings of the gluten are made out of the sieve.

The whole of the turbid washings are to be put into a tall conical glass or stoneware vessel, and allowed to remain at rest, in a cool place, till they deposite the starch. The clear supernatant liquor is then decanted off. The deposite consists of starch, with a little gluten. It must be washed till the water settles over it quite clear, and then it is to be dried.

The filtered waters being evaporated at a boiling heat, discover flocks floating through them, which have been supposed by some to be albumen, and by others gluten. At last, phosphate of lime precipitates. When the residuum has assumed a sirupy consistence in the cold, it is to be mixed with alcohol, in order to dissolve out its sugar. Cold water being added to what remains, effects a solution of the mucilage, and leaves the insoluble azotized matter with the phosphate of lime.

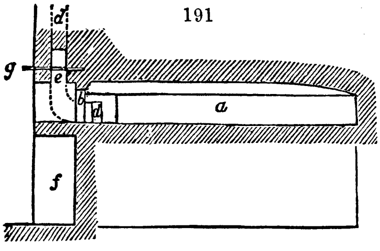
By this mode of analysis a minute portion of resin may remain in the gluten and in the washing water; the gluten retains also a small proportion of a fixed oil, and a volatile principle, which may be removed by alcohol. If we wish to procure the resin alone, we must first of all treat the flour, well dried, with alcohol.

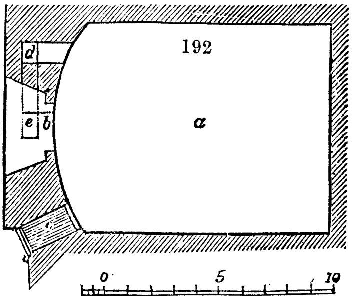
When corn flour, poor in gluten, is to be analyzed, the dough must be enclosed in a linen bag, kneaded with water, and washed in that state.

In analyzing barley-meal by the above process, *hordeine*, mixed with common starch, is obtained: they may be separated by boiling water, which dissolves the starch, and leaves the hordeine under the aspect of saw-dust.

Fig. 191 is the plan of a London baker's oven, fired with coal fuel.

Fig. 192 is the longitudinal section.





a, the body of the oven; *b*, the door; *c*, the fire-grate and furnace; *d*, the smoke flue; *e*, the flue above the door, to carry off the steam and hot air, when taking out the bread; *f*, recess below the door, for receiving the dust; *g*, damper plate to shut off the steam flue; *h*, damper plate to shut off smoke flue, after the oven has come to its proper

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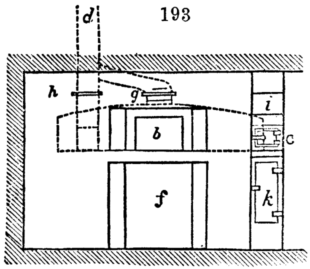

heat; *i*, a small iron pan over the fire-place *c* for heating water; *k*, ash-pit below the furnace.

Fig. 193 is the front view; the same letters refer to the same objects in all the figures.

The flame and burnt air of the fire at *c*, sweep along the bottom of the oven by the right hand side, are reflected from the back to the left hand side, and thence escape by the flue *d*; (see plan *fig.* 193.) Whenever the oven has acquired the proper degree of heat, the fire is withdrawn, the flues are closed by the damper plates, and the lumps of fermented dough are introduced.

I believe it may be safely asserted that the art of baking bread, pastry, and confectionery, is carried in Paris to a pitch of refinement which it has never reached in London. I have never seen here any bread which, in flavour, colour and texture, rivalled the French *pain de gruau.* In fact, our corn monopoly laws, till they were of late happily repealed, prevented us from getting the proper wheat for preparing, at a moderate price, the genuine *semoule* out of which that bread is baked. Hence, the plebeian *bourgeois* can daily grace his table with a more beautiful piece of bread than the most affluent English nobleman. The French process of baking has been recently described, with some minuteness, by their distinguished chemist, M. Dumas*, and it merits to be known in this country.

At each operation, the workman (*pétrisseur*) pours into the kneading trough the residuary leaven of a former kneading, adding the proportion of water which practice enjoins, and diffuses the leaven through it with his hands. He then introduces into the liquid mass the quantity of flour destined to form the sponge (*pâte*). This flour is let down from a chamber above, through a linen hose (*manche*), which may be shut by folding it up at the end.

The workman now introduces the rest of the flour by degrees, diffusing and mingling it, in a direction from the right to the left end of the trough. When he has thus treated the whole mass successively, he repeats the same manipulation from left to right. These operations require no little art for their dextrous performance; hence they have the proper name assigned respectively to each, of *frasage* and *contre-frasage.* The workman next subjects the dough to three different kinds of movement, in the kneading process. He malaxates it; that is, works it with his hands and fingers, in order to mix very exactly its component parts, while he adds the requisite quantity of flour. He divides it into six or seven lumps (*pâtons*), each of which he works successively in the same manner. Then he seizes portions of each, to draw them out, taking only as much as he can readily grasp in his hands. When he has thus kneaded the different lumps, he unites them into one mass, which he extends and folds repeatedly back upon itself. He then lifts up the whole at several times, and dashes it forcibly against the kneading trough, collecting it finally at its left end. The object of these operations is to effect an intimate mixture of the flour, the water, and the leaven. No dry powdery spots called *marrons*, should be left in any part of the dough.

The kneader has now completed his work; and after leaving the dough for some time at rest, he turns it upside down. He lays the lumps, of a proper weight, upon a table, rolls them out, and dusts them with a little flour. He next turns over each lump, and puts it in its *panneton*, where he leaves it to swell. If the flour be of good quality, the dough be well made, and the temperature be suitable, the lumps will swell much and uniformly. If after the surface has risen, it falls to a considerable extent, the flour must be bad, or it must contain other substances, as potato starch, bean meal, &c.

Whenever the oven is hot enough, and the dough sufficiently fermented, it is subjected to the baking process. Ovens, as at present constructed, are not equally heated throughout, and are particularly liable to be chilled near the door, in consequence of its being occasionally opened and shut. To this cause M. Dumas ascribes many of the defects of ordinary bread; but he adds, that by adopting the patent invention of M. Mouchot these may be obviated. This is called the ***improved bakery, boulangerie perfectionnée.***

Fig. 194. is a ground plan of the aerothermal bake-house, the granaries being in the upper stories, and not shown here. *b b* are the ovens; *c*, the kneading machine; *d*, the place where the machinery is mounted for hoisting up the bread into the store room above; *e*, a space common to the two ovens, into which the hot air passes; *f*, the place of a wheel driven by dogs, for giving motion to the kneading machine.

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* Traité de Chimie appliquée aux Arts, vi. p. 400.

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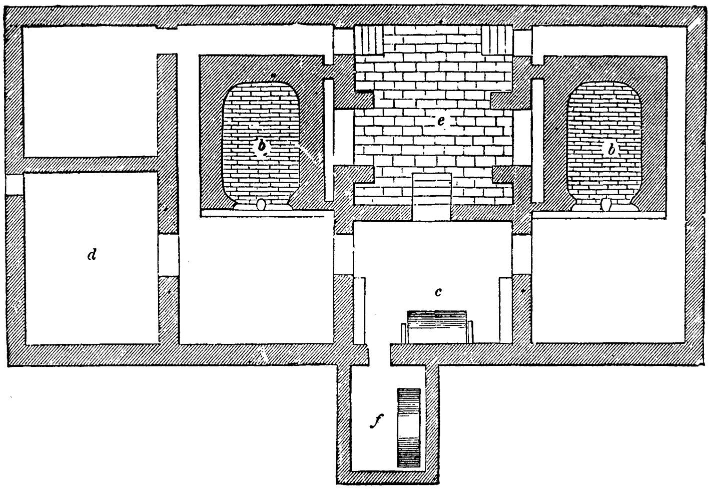
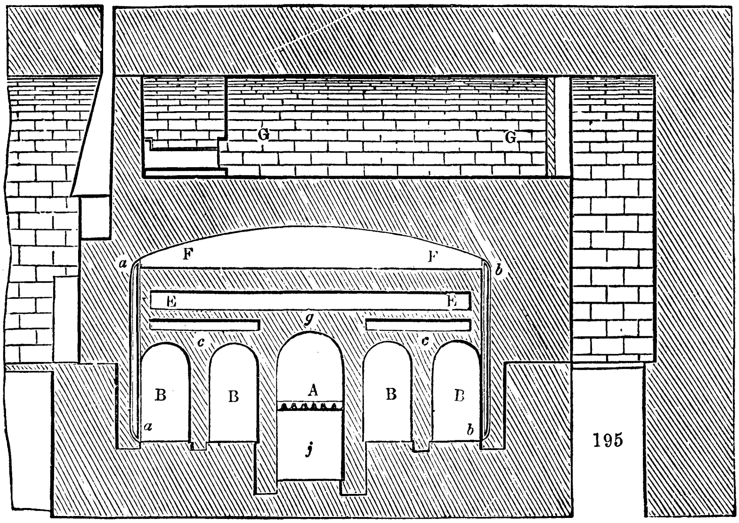


Fig. 195. is a longitudinal section of the oven; A, the grate where coke or even pit-coals may be burned; B, B, void spaces which, becoming heated, serve for warming small pieces of dough in; *c*, *c* are flues for conducting the smoke, &c., from the fire-place; D, seen in *fig.* 196., is the chimney for carrying off the smoke transmitted by the flues; E, E, void spaces immediately over the flues, and beneath the sole, F, F, of the oven. By this arrangement the air, previously heated, which arrives from the void spaces B through the flues, *c*, *c*, gets the benefit of the heat of the flame which circulates in these flues, and, after getting more heated in the spaces E, E, ascends through channels into the oven F, F, upon the sole of which the loaves to be baked are laid.



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The hot air is admitted into it through the passages *a*, *a*, being drawn from the reservoirs B, B, B, and also by the passage *d*, *d*, drawn from the reservoirs E, E. The sole is likewise heated by contact with the hot air contained in the space E, E, placed immediately below it. The hot air, loaded with moisture, issues by the passage *b*, *b*, and returns directly into the reservoir B, B. G, G, an enclosed space directly over the oven, to obstruct the dissipation of its heat; *g*, vault of the fire-place. *Fig.* 196., a transverse section through the middle of the oven. *Fig.* 197., the kneading machine, a longitudinal section passing through its axis; P, P, the contour of the machine, made of wood, and divided into three compartments for the reception of the dough. The wooden bars, *o*, *o*, are so placed in the interior of the compartments, as to divide the dough whenever the cylinder is made to revolve. One portion, D, of the cylinder may be opened and laid over upon the other by means of a hinge joint, when the dough and flour are introduced. A, B, C, the three compartments of the machine, two for making the dough, and one for preparing the sponge, called *levain*, or leaven, by the French. *a*, *a*, is the pulley which receives its motion from the engine, and transmits it to the cylinder through the pinion *b*, and the spur-wheel *e; d d*, the fly-wheel to regulate the motion; *g*, a brake to act upon the fly *d*, by means of a lever *h; i*, the pillar of the fly-wheel. There is a ratchet wheel counter for numbering the turns of the kneading machine, but it cannot be shown in this view; *n*, cross bars of wood, which are easily removed when the cylinder is opened; they divide the dough.

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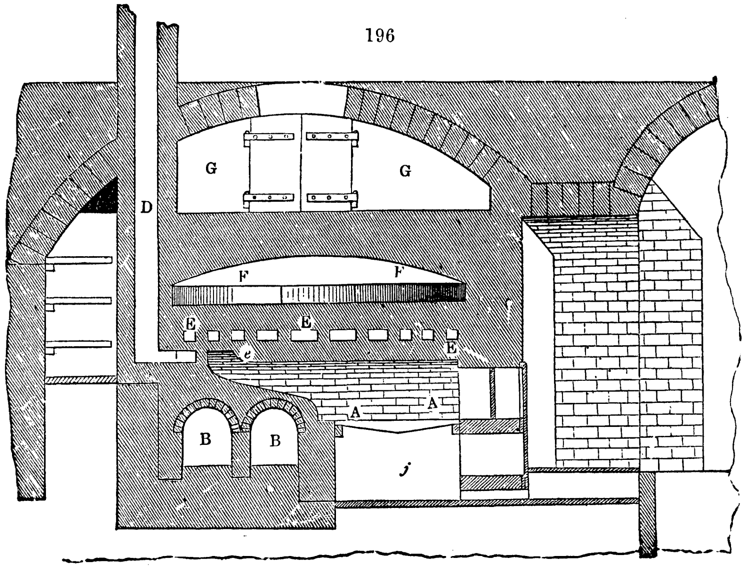

Each of the three compartments of the *kneader* (*fig.* 197.) is furnished at pleasure with two bars fixed crosswise, but which may be easily removed, whenever the cylinder is opened. These bars constitute the sole agents for drawing out the dough.

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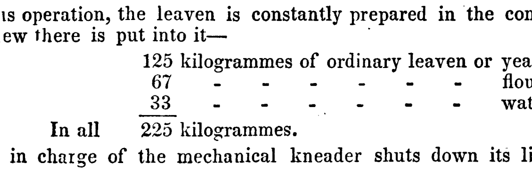

In a continuous operation, the leaven is constantly prepared in the compartment A; with which view there is put into it—

	125	kilogrammes of ordinary leaven or yeast.
	67	flour.
	33	water.
In all	225	kilogrammes.

The person in charge of the mechanical kneader shuts down its lid, and sets it a-going. At the end of about seven minutes he hears the bell of the counter sound, announcing that the number of revolutions has been sufficient to call for an inspection of the sponge, in regard to its consistence. The cylinder is therefore opened, and after verifying the right state of the leaven, and adding water to soften, or flour to stiffen it, he closes the lid, and sets the machine once more in motion. In ten minutes more the counter sounds again, and the kneading is completed. The 450 kilogrammes of leaven obtained from the two compartments are adequate to prepare dough enough to supply alternately each of the two ovens. For this purpose 75 kilogrammes of leaven are taken from each of the two compartments A and A′, and placed in the intermediate compartment B. The whole leaven is then 75+75=150 kilogrammes; to which are added 100 kilogs. of flour and 50 of water=150, so that the chest contains 300 kilogrammes. There is now replaced in each of the cavities A and A′ the primitive quantity, by adding 50 kilogrammes of flour and 25 of water=75.

The cylinder is again set a-going; and from the nature of the apparatus, it is obvious that the kneading takes place at once on the leavens A and A′ and on the paste B; which last is examined after 7 minutes, and completed in 10 more=17, at the second sound of the counter-bell.

The kneader is opened, the paste on the side and on the bars is gathered to the bottom by means of a scraper. The whole paste of the chest B being removed, 150 kilogs. of the leaven are taken, to which 150 kilogs. of flour and water are added to prepare the 300 kilogs. of paste destined for the supply of the oven No. 2. These 75 kilogs. of leaven from each compartment are replaced as before, and so on in succession.

The water used in this operation is raised to the proper temperature, viz. 25° or 30° C. (77° or 86° F.) in cold weather, and to about 68° F. in the hot season, by mixing common cold water with the due proportion of water maintained at the temperature of about 160° F., in the basin F placed above the ovens.

Through the water poured at each operation upon the flour in the compartment B, there is previously diffused from 200 to 250 grammes of fresh leaven, as obtained from the brewery, after being drained and pressed (*German yeast*). This quantity is sufficient to raise properly 300 kilogs. of dough. As soon as this dough is taken out of the kneader, as stated above, and while the machine goes on to work, the quantity requisite for each loaf is weighed, turned about on the table D, to give it its round or oblong form, and there is impressed upon it with the fore-arm or roller, the cavity which characterizes cleft loaves. All the lots of dough of the size of one kilog., called cleft loaves (*pains fendus*) are placed upon a cloth a fold of which is raised between two loaves, the cloth being first spread upon a board; which thus charged with 10 or 15 loaves is transferred to the wooden shelves G G in front of the oven.

The whole of them rise easily under the influence of the gentle temperature of this antechamber or *fournil*. Whenever the dough loaves are sufficiently raised here, they are put into the oven, a process called *enfournement* in France; which consists in setting each loaf on a wooden shovel dusted with coarse flour, and placing it thereby on the sole of the oven, close to its fellow, without touching it. This operation is made easy, in consequence of the introduction of a long jointed gas-pipe and burner into the interior of the oven, by the light of which all parts of it may be minutely examined. The oven is first kept moderately hot, by shutting the dampers; but whenever the thermometer attached to it indicates a temperature of from 300° to 290° C. (572° to 554° F.), the dampers or registers are opened, to restore the heat to its original degree, by allowing of the circulation of the hot air, which rises from the lower cavities around the fire-place into the interior of the oven. When the baking is completed, the gas-light, which had been withdrawn, is again introduced into the oven, and the bread is taken out; called the process of *défournement*. If the temperature have been maintained at about 300° C., the 300 kilogs. of dough divided into loaves of one kilog. ($2\frac{1}{5}$ lbs. avoirdupois) will be baked in 27 minutes. The charging having lasted 10 minutes, and the discharging as long, the baking of each batch will take up 47 minutes. But on account of accidental interruptions, an hour may be assigned for each charge of 260 loaves of 1 kilog. each; being at the rate of 6240 kilogs. (or 6·75 tons) of bread in 24 hours.

Although the outer parts of the loaves be exposed to the radiation of the walls, heated to 280° or 300° C., and undergo therefore that kind of caramelization (charring) which produces the colour, the taste, and the other special characters of the crust, yet the inner substance of the loaves, or the crumb, never attains to nearly so high a temperature; for a thermometer, whose bulb is inserted into the heart of a loaf, does not indicate more than 100° C. (212° F.).

The theory of *panification* (bread-baking) is easy of comprehension. The flour owes this valuable quality to the gluten, which it contains in greater abundance than

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any of the other *cerealia* (kinds of corn). This substance does not constitute, as had been heretofore imagined, the membranes of the tissue of the perisperm of the wheat; but is enclosed in cells of that tissue under the epidermic coats, even to the centre of the grain. In this respect the gluten lies in a situation analogous to that of the starch, and of most of the immediate principles of vegetables. The other immediate principles which play a part in *panification* are particularly the starch and the sugar; and they all operate as follows:—

The diffusion of the flour through the water, *hydrates* the starch and dissolves the sugar, the albumen, and some other soluble matters. The kneading of the dough, by completing these reactions through a more intimate union, favors also the fermentation of the sugar, by bringing its particles into close contact with those of the leaven or yeast; and the drawing out and malaxating the dough softens and stratifies it, introducing at the same time oxygen to aid the fermentation. The dough, when distributed and formed into loaves, is kept some time in a gentle warmth, in the folds of the cloth, pans, &c., a circumstance propitious to the development of their volume by fermentation. The dimensions of all the lumps of dough now gradually enlarge, from the disengagement of carbonic acid in the decomposition of the sugar; which gas is imprisoned by the glutinous paste. Were these phenomena to continue too long, the dough would become too vesicular; they must, therefore be stopped at the proper point of sponginess, by placing the loaf lumps in the oven. Though this causes a sudden expansion of the enclosed gaseous globules, it puts an end to the fermentation, and to their growth; as also evaporates a portion of the water.

The fermentation of a small dose of sugar is, therefore, essential to true bread-baking; but the quantity actually fermented is so small as to be almost inappreciable. It seems probable that in well-made dough the whole carbonic acid that is generated remains in it; amounting to one half the volume of the loaf itself at its baking temperature, or 212°. It thence results that less than one hundredth part of the weight of the flour is all the sugar requisite to produce well-raised bread. What egregious folly was it, therefore, to mount the bakery in Chelsea, twelve years ago, at an expense of 20,000*l.*, for the purpose of *catching the volatile spirits* in their escape from the loaves in the oven—or, as it was vulgarly termed, "taking the gin out of the bread!" whereas it was nothing but taking the cash out of the pockets of the pseudo-chemical visionaries who swarm in this metropolis.

The richness or nutritive powers of sound flour and also of bread are proportional to the quantity of gluten they contain. It is of great importance to determine this point, for both of these objects are of enormous value and consumption; and it may be accomplished most easily and exactly by digesting in a water-bath, at the temperature of 167° F., 1,000 grains of bread (or flour) with 1,000 grains of bruised barley-malt, in 5,000 grains, or in a little more than half a pint, of water. When this mixture ceases to take a blue color from iodine (that is, when all the starch is converted into soluble dextrine) the gluten left unchanged may be collected on a filter cloth, washed, dried at a heat of 212°, and weighed. The color, texture, and taste of the gluten, ought also to be examined, in forming a judgment of good flour, or bread.

Independently of the skill of the baker, bread varies in quality according to the quantity of water and gluten it contains. A patent of German or French origin was obtained here a few years ago, for manufacturing loaf-bread by using thin boiled flour-paste instead of water for setting the sponge, that is, for the preliminary dough fermentation. By this artifice, 104 loaves of 4 lbs. each could be made out of a sack of flour, instead of 94, as in ordinary baking; because the boiled paste gave a water-keeping faculty to the bread in that proportion. But this *hydrated* bread was apt to spoil in warm weather, and became an unprofitable speculation to all concerned.

Bread and flour are often adulterated in France with potato starch, but almost never, I believe, in this country. The sophistication is easily detected by the microscope, on account of the peculiar ovoid shape and the large size of the particles of the potato fecula. Horse-bean flour gives to wheaten bread a pinkish tint. In spoiled flour (such as is too often used, partially at least, by our inferior bakers) the gluten sometimes disappears altogether, and is replaced by ammoniacal salts.* In this case quicklime separates ammonia from the flour without heat; in flour slightly damaged, or ground from damaged wheat, the gluten present is deprived of its elasticity, and is softer than in the natural state. On this account the gluten test of M. Boland is valuable. It consists in putting some gluten into the bottom of a copper tube, and heating that tube in an oven, or in oil at a temperature of 284° F. The length to which the cylinder of gluten expands is proportional to and indicates its quality.

It appears that a French sack of flour, which weighs 159 kilogrammes, affords from 102 to 106 loaves of 2 kilogrammes each: and therefore,

159 . 52·0 :: 280 : 91·6; that is, if 159 kilogs. or lbs. afford 52 loaves of 4 kilogs. or lbs., 280 lbs., a sack English, should afford 91·6 loaves of 4 lbs. each; but our

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* Dumas, Chimie Appliquée, vi. 425.

bakers usually make out 94 loaves, which are rated at 4 pounds, though they seldom weigh so much. The loaves of a baker in my neighbourhood, who supplied my family with bread for some time, were found on trial to be from 6 to 8 oz. deficient in weight: when challenged for this fraud, he had the effrontery to palliate it by alleging that all his neighbour bakers did the same. It must be borne in mind that a Paris loaf of 2 lbs. or 2 kilogs. contains more dry farina than a London loaf of like weight; for it contains, from its form and texture, more crust. The crumb is to the crust in the Paris long loaves, as 25 to 75, or 1 to 3; in our quartern loaves it is as 18 or 20 to 100

M. Dumas gives the following Table :—

Weight of a Sack of Flour.	Number of Loaves.	Weight of the Bread.	Increase of Weight of Flour.	Ratio of dry Flour = 1. to Bread.
159 Kilogs.	102	202 Kilogs.	1·283	
159 do.	104	208 do.	1·300	1 : 1·60
159 do.	106	212 do.	1·333	

Thus it would appear that the mean yield would correspond to 130 kilogs. of bread for 100 of the flour employed: and admitting that common flour contains 0·17 of water, the product would be equivalent to 150 of bread for 100 of flour absolutely dry. The whole loaf contains 66 per cent. of dry substance, and the crumb only 44.

BRECCIA, an Italian term, used by mineralogists and architects to designate such compound stony masses, natural or artificial, as consist of hard rocky fragments of considerable size, united by a common cement. When these masses are formed of small rounded pebbles, the conglomerate is called a pudding-stone, from a fancied resemblance to plum pudding.

Concrete, now so much used for the foundation of large buildings, is a factitious breccia, or pudding-stone. See CONCRETE.

BREWING. (*Brasser*, Fr.; *Brauen*, Germ.) The art of making BEER, which see.

The peculiar properties contained in wort, do not exist ready formed in malt, but are the result of the direct action of heat and water upon that substance. Hence it follows that the composition of beer-wort depends more upon the process of mashing than upon the malt employed,—for it would be quite practicable to obtain from 1 part of malt and 8 parts of barley, a wort precisely similar to that procured from 9 parts of pure malt alone. But, of course, this could not be done without modifying considerably the process of mashing; and it happens, unfortunately, that the practice of the present day, amongst brewers, is to maintain, as closely as possible, one uniform system of mashing, whatever may be the nature or quality of the malt employed. Thus a difference in the malt is made to produce a difference in the wort, and all the energy and skill of the practical brewer are sometimes insufficient to compensate for the alterations which this difference induces in the subsequent working of the beer. With a regular and certain composition, as to the constituents of his wort, the operations of the brewer would assume a fixed and definite character, which, at present, they are very far indeed from possessing; and by which he not unfrequently suffers the most severe pecuniary loss and mental anxiety. With the exception of a trifling quantity of vegetable albumen, the only solid ingredients of beer-wort are dextrine and sugar; the latter of which ferments with great ease and rapidity, whilst the dextrine, though capable of fermentation, enters into the process only with difficulty, and requires, for its successful termination, not only much more yeast, but also a much higher temperature in the fermenting fat. At the same time, it is this very sluggishness in the fermentative quality of dextrine which is essential to the production of good beer; for, with sugar alone, the fermentation cannot be checked at ordinary temperatures, until the full measure of its decomposition has taken place, and it has become either a vapid admixture of alcohol and water, or, by the absorption of oxygen, is resolved into vinegar. It is indeed a notorious fact, that beer made with sugar will not keep so well as that made from malt; though, for rapid consumption, the use of sugar is, under some circumstances, to be commended, more especially on the small scale and in cold weather. The peculiarity of dextrine is, however, as we have stated, to undergo fermentation only with difficulty and by slow degrees; hence its decomposition spreads over a long space of time, and, in very cold weather, amounts to nothing; so that for months, or even years, after all the sugar of the wort has been destroyed, the evolution of carbonic acid gas from the still fermentiug dextrine, keeps up a briskness and vitality in the beer; and, by excluding oxygen, all chance of acidification is shut off. A perfect beer-wort should therefore have reference to the period of its consumption: if this be speedy and pressing, the proportion of sugar ought to be large; if remote, the dextrine should greatly predominate. Under the first condition, the attenuation would proceed quickly and, provided the temperature of the fermenting vat was not allowed to exceed 78°, the beer would soon cleanse and become ripe and bright; under the second, the attenuation in

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the vat would be slow and trifling, and require, perhaps, several years for its completion in the cask. Nevertheless, if the attenuation in the vat had gone on to the complete destruction of all the sugar, this kind of beer would prove in the end both the better and more healthy beverage of the two; for by the mode of its formation the presence of ænanthic ether or fusel oil is avoided. The importance therefore of placing in the hands of the brewer a means of determining the relative amounts of sugar and dextrine in his wort is sufficiently obvious. Now, this may be done in two ways; either by ascertaining, in wort of a determinate strength, the proportion of the one or the other of these substances. The dextrine is easier of calculation than the sugar, in a rough or approximate way; but the sugar can be determined with much more minute accuracy than the dextrine. Yet, in practice, the former plan is preferable, from its simplicity, as we shall proceed to show. If, to a certain volume of strong wort (say of 30 lbs. per barrel), we add an equal amount of alcohol or spirits of wine, the whole of the dextrine will precipitate as a dense coagulum; and by examining the bulk of this deposit in the tube, its weight may be inferred pretty nearly if the tube has been previously graduated so as to indicate, from actual experiment, the weight of the different measures of the coagulated dextrine. With weaker wort, more alcohol must be used, and with a denser wort, less alcohol,—the relations of which to each other may easily be kept recorded on a small card or scale affixed to the tube. This instrument is very easy of application, and has been found extremely useful to more than one practical brewer of the present day; and the accompanying record of brewing operations has reference to this mode of analysing wort. The determination of sugar in wort is best effected by boiling 100 grs. of it with about half a pint of the following solution, and collecting and weighing the red-coloured precipitate which ensues,—every three grains of which indicate one grain of grape-sugar in the wort.

Grape sugar Test Solution.

Sulphate of copper in crystals	100 grains
Bitartrate of potash	200 do
Carbonate of soda in crystals	800 do
Boiling water, one pint, or	8750 do

First dissolve the sulphate of copper, **then the** bitartrate of potash, after which add the carbonate of soda, and filter if necessary. This solution is not affected when boiled with cane-sugar, dextrine, gum, or starch.

We now proceed to lay before our readers the result of two brewings taken from one mash at two different periods, and analyzed to determine their relative contents of dextrine and sugar, according to the tube or alcohol process:—March 28th, 1851, proceeded to mash for experimental brewings; weather clear and open; thermometer outside at 51°,—in fermenting room 58°; difference between wet and dry bulb 5·750°; barometer 39·4 inches. Composition of the malt:—Moisture 6·1; insoluble matter 27; extract 66·9. Quantity of malt employed 70 bushels; of water at 180° F., 700 gallons; made the mixture with a common mashing-oar, and finished in fifteen minutes. One hour afterwards, drew off 200 gallons of wort; and three hours from commencing to mash, drew off 200 gallons more,—continuing the mash for table-beer-wort. The first-drawn wort contained 7·5 parts of dextrine to 1 of sugar; the second, 6·3 parts of dextrine 2·2 of sugar;—their densities were, respectively, 30 and 36·5 lbs. per barrel. They were each boiled separately, with relative amount of hop,—the first having 30 and the second 36½ lbs. added; and the boiling in each case was kept up for three hours. At the end of this time both were cooled and diluted with water to a gravity of 27½ lbs. per barrel, and 250 gallons of each let down into separate fermenting-vats placed side by side; after which, they both received three quarts of good yeast,—the temperature being at 68° F. Two hours afterwards, the following observations commenced:—No. 1. being the wort containing 7·5 parts of dextrine to 1 of sugar, and No. 2. the wort having 6·3 of dextrine to 2·2 of sugar.

1851.	No. 1.	Temp.
March 28. 5 P. M.	No action	67·5
" " 10 P. M.	Light thin cream	67·5
" 29. 9 A. M.	White head	70·
" " 6 P. M.	Fine white head	71·
" 30. 9 A. M.	Thick tough head	74·
" " 6 P. M.	Tough brown head	75·
" 31. 2 P. M.	Ferment well roused up	75·
		Deg.
	Attenuation of No. 1.	8½
April 2. 2 P. M.	(Skimmed off yeast)	10·
" 11. 2 P. M.	" "	15·
" 13. 2 P. M.	" "	15·5

No. 2.	Deg
No action	68·
Fine white head	70·
Thick yellow head	74·
Fine tough brown head	77·
High roused up rocky head	77·
In rapid fermentation	76·5
Throws up much yeast (skimmed off yeast)	76·
Ditto of No. 2.	12·7
" "	15·5
" "	17·5
" "	18·2

The temperature of both had now fallen to 69° F., though each had been roused repeatedly; the yeast was, therefore, again skimmed off, and the beer run into barrels, and filled up with reserved wort three times a day as it worked over. On April the 18th the barrels were closed, having then lost, by attenuation,—No. 1. 16·2 lbs., and No. 2. 19·6 lbs. Six weeks afterwards these ales were examined;—No 1. was found muddy and unpleasant; whilst No. 2. had a fine fragrant aroma, a brisk, lively appearance, and was perfectly bright. On January 2nd, 1852, the casks were again examined; No. 1. had now lost 17·9 lbs., and was bright, rich, and fine flavoured; whilst N. 2., though bright and pleasant, had contracted a little acidity, and was becoming flat; it had lost, in all, 21½ lbs.

Two similar experiments, made about the same time in another quarter, gave almost exactly the same results; and, consequently, there can be little doubt that, where a quick sale and rapid consumption of beer can be ensured, the great object of the brewer should be to convert as much of the dextrine of his wort into sugar as is proportional to the rapidity of that consumption; whereas, for beer intended to keep, the opposite practice should be followed.

The conversion of any given amount of the dextrine wort into sugar may be effected either by keeping up the temperature of the mash-tun, and prolonging the operation of mashing: or, which is better and simpler, by merely preserving the wort for a few hours at a heat of 170° F., either in the underback or any other convenient vessel. We have found from experiment that a wort which when run out from the mash-tun had only 3 parts of sugar to 16 of dextrine, became by 10 hours' exposure to a heat of 165° converted almost altogether into sugar,—the proportions then being 17·8 of sugar to 1·2 of dextrine.

A very important part of the duty of a brewer should therefore be, first, the determination of the relative amounts of dextrine and sugar required to suit the taste of his customers, or the circumstances of the market, and next, the continued careful examination of his wort, so as to insure that these proportions are regularly maintained; for by no other plan is it possible to insure that certainty of result, and uniformity of quality which are essential to the proper conducting of an expensive business like brewing. It seems to us that far too little attention has hitherto been given to the fluctuating qualities of beer-wort. In warm weather, this wort should probably contain at least twice as much dextrine as in winter; yet this is the very period when from the increased temperature of the air and materials, the largest quantity of sugar must be formed by those who mash upon a fixed and unvarying principle. Hence the proneness of the wort to ferment violently in summer is still further increased by the presence of an extra proportion of sugar;—whereas prudence would suggest, under such circumstances, a predominance of dextrine, and seek to effect this purpose by a low temperature in the mash-tun, and by shortening the period of mashing. We are not, however, aware that this custom prevails, except in one or two solitary instances, in the north of England, where it is well appreciated. As a general rule, in the management of wort, more sugar is requisite where small quantities are brewed at a time, than where large operations are conducted, for the loss of heat is relatively larger in small masses than in large ones; and, from what has been stated, it must be apparent, that, as the fermentation of dextrine is more easily checked by cold than that of sugar, the beer brewed in trifling quantities could not preserve a fermentative temperature, but would become chilled and dead from the excessive radiation of caloric, unless a principle existed in it capable of fermentation at the most ordinary temperatures of this country. If, therefore, beer-wort consisting chiefly of dextrine be fermented in very cold weather, or with an insufficiency of yeast, or if the temperature happen to rise too high, so as to destroy or impair the fermentative power of the yeast, then a dull languid action will ensue, accompanied by what has been called the viscous fermentation, and the beer becomes permanently ropy, and is spoiled.

Although, clearly, it would be impossible to lay down any specific rule for the proper proportion of dextrine and sugar in beer-wort, yet there could be no difficulty in each brewer determining for himself, and for the conditions of size, time of sale, time of year, and other contingencies, the requisite ratio to be established in his own case; and, as we have shown, nothing can be simpler than the means proposed for ascertaining the composition of wort.

The advance of the arts is gradually assuming a character which will no longer permit any manufacturer to neglect the assistance of science; and those who first take advantage of the power of knowledge, will assuredly leave their fellow-labourers behind. From being an uncertain and hazardous operation, brewing must ere long become a fixed and definite principle based upon facts well understood, and capable of perpetual repetition and reproduction at will. To sum up briefly the general details of ale brewing, we may state, that, for most kinds of ale, the attenuation in the first instance should be finished in from 6 to 21 days, according to the strength of the wort; that this attenuation should approach to two-thirds of the whole weight; and that after tunning and cleansing, the ale itself should weigh about one-fourth of the original gravity of the wort. Thus, if the fermenting tun be set with wort of 27 lbs., then the attenuation should bring it down to 9 or 10 lbs., and the subsequent operations produce an ale weighing from 6 to 7 lbs. When these conditions are fulfilled, without much extra trouble or attention, the ale is pretty certain to turn out well, though, in some localities, ale is never attenuated to more than one-half its original gravity; this kind of ale is, however, very apt to become sour in hot weather and ropy in cold.

We will now proceed to describe the brewing of porter, which differs from that of ale both in the nature of the materials used and in the mode of finishing the fermentation. Porter owes its peculiar colour and flavour to burnt saccharine or starchy matter; and this was formerly obtained by burning sugar until it exhaled the odour called by French writers "caramel." At present, however, nothing but highly-torrefied malt is used; and of this there are several kinds, as brown malt, imperial malt, and black malt; all of which are used by some brewers, whilst others employ only the brown and black, and a few the black alone, for giving colour and flavour. The fermentative quality is saccharine, is, however, the same as that of ale, and is derived from pale or amber malt. As a general rule, the ratio of the colouring and flavouring malts are to the saccharine, as about 1 to 5, or 1 to 4; but where black malt only is used, the proportion does not exceed 1 to 10.

The employment of these burnt malts permits a singular act of injustice on the part of the Excise, as regards the drawback on exportation. By the Excise regulations, it is assumed that a quarter of malt will produce four barrels of ale brewed from wort of the sp. gr. 1·054, or 19·4 lbs. per barrel; but, although this is hopeless even with pale malt, yet with an admixture of brown and black malt the assumption becomes absurd in the extreme. Admitting that, by good management, on the average, four barrels of wort, weighing 20 lbs., can be obtained from one quarter of fine pale malt, yet in the operations of cooling, fermenting, tunning, skimming, and cleansing, a loss of fully 10 per cent. occurs under the most vigilant superintendence; and, taking the great bulk of our metropolitan breweries, it would be nearer the truth to estimate this loss at 12 per cent. In plain words, 100 gallons of wort will not, by any management, produce more than about 88 gallons of saleable beer, though no allowance is made for this by the Excise; and the brewer who has paid duty upon 100 gallons gets a drawback upon but 88. This, however, is the most favourable view of the case; and we solicit attention to the force with which the argument returns in the instance of porter.

If a quarter of pale malt be assumed at 84 lbs. of saccharine strength, then such an admixture of brown and black malt as is usually employed by brewers of porter, will not give more than about 24 lbs.; and as this constitutes at least one-fifth of the whole bulk used in porter brewing, we see that a quarter of such mixed malt can never give more than 70 lbs.; that is to say, 80 parts of pale malt, mixed with 20 of brown and black, instead of giving at the rate of 84 lbs., as pale malt alone does, would give but 70 lbs., or produce a difference between the actual return and that taken for granted by the Excise authorities, of no less than 16·6 per cent; to which, if we add the loss previously mentioned as arising from fermentation, yeast, &c., and which we have called 12 per cent., a total difference ensues of 28·6 per cent. between the duty paid by the brewer and the drawback allowed by act of parliament. But the grievance does not stop here; for the only return allowed by act of parliament is based upon the malt duty, and nothing whatever is said of the duty on hops. This, however, is at the rate of 19*s.* 7*d.* per cwt.; and since hops yield only about 35 per cent. of their weight of soluble matter, it would require 168 lbs. of hops to produce a barrel of fluid or wort weighing 19·4 lbs., or having the requisite parliamentary specific gravity of 1·054. Upon this barrel, when exported, the drawback is 5*s.*; but as may easily be seen, on calculation, the duty paid by the brewer has been 29*s.* 3*d.* In fact, upon every 168 lbs. of hops consumed by the export brewer, he suffers a dead loss of 24*s.* 3*d.*, independently of the waste incidental to his various processes. These things may seem startling, yet I challenge

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the whole Board and Staff of the Excise to prove that they are in the least over-estimated. At the same time the intelligent reader will gather that the profits of brewing are not by any means so large as a cursory glance at the subject might warrant; and we say this rather as having reference to schemes now in progress for reducing the price of beer, than from its connection with our general arrangements. No doubt the brewing business has been of late singularly prosperous; and if the price of malt continues as low this year as it was last, the public have a right to look for some reduction in the price of ale and porter; but it must not be forgotten that the capital required is large, and invested in very perishable materials, such as casks and other wooden utensils, the wear and tear upon which is a very large item; nor again, as we have shown, must a speculator begin by assuming, with the Excise authorities, that a quarter of malt will produce four barrels of beer, for he will be much nearer the truth if he estimates his saleable produce at three barrels. As, however, it forms no part of our present task to enter into the financial statistics of brewing, we return to the object more immediately in view, merely throwing out, *en passant*, the above hints for the benefit of those whom they may concern.

If the analyses of malt and malt-wort are requisite to enable the brewer to perform his operations with safety and success, the analysis of beer is not less indispensable to qualify him for the harassing labour of competition with his neighbours, and for the protection of his interest against Excise confiscation. Although beer may have been brewed of the requisite gravity for justifying a drawback on exportation, yet this is very far indeed from ensuring a return of the malt duty, even to the limited extent awarded by law. The question is, how are the Excise officials to know the real weight of the wort from which the beer was brewed. This may be ascertained by the following method, which should take the place of the present indefinite system:—Having agitated a portion of the ale or beer, so as to dissipate its carbonic acid gas, measure out exactly 3600 grain measures of it, and pour these into a retort; then distil, with great care, into a receiver, surrounded by ice-cold water, about one-third of the whole fluid, or rather more than this if the ale or beer is known to be highly alcoholic. Next weigh the distilled fluid, and then ascertain its specific gravity; from whence, by any of the proper tables of *alcohol* (which see), the total quantity of absolute alcohol in the distilled fluid may be known. This alcohol is to be converted, by calculation, into its equivalent of sugar, at the rate of 171 parts of sugar for every 92 of alcohol found; after which, this sugar must be brought into pounds per barrel, by the rule given in our article Beer, which is 52½ lbs. of sugar for every 20 lbs. of gravity. The amount of vinegar is next to be determined, by any of the known forms of alkalimetry. (See Acetic Acid.) This vinegar or acetic acid must, like the alcohol, be also converted into its representative of sugar, by assigning 171 of sugar to every 102 of anhydrous acetic acid present in the beer,—this sugar being, as before, converted into pounds per barrel. To the beer remaining in the retort, sufficient distilled water is then to be added, that the entire bulk of fluid may once more be equal to 3600 grain measures; and the temperature of the mixture having fallen to 60° Fahr., its specific gravity must be determined in the usual way, and this reduced to pounds per barrel, by multiplying the excess above 1000 by 360, and dividing the product by 1000. The whole of these weights, added together, gives the original weight of the wort. Thus, for example, we will suppose that 3600 grs. of a particular beer have given 1300 gr. of a dilute alcohol, of specific gravity ·9731, and consequently containing about 17½ per cent., by weight, of alcohol; again, that the same quantity of beer, when tested by ammonia, has indicated 30 grs. of acetic acid; and, lastly, that the spent wash, when filled up with distilled water to its primary bulk, has, at 60°, a specific gravity of 1·016;—then the total alcohol would be in 360 grs., or the representative of a barrel, 22¾ grs., and the acetic acid in the same quantity, 3 grs.: hence we have the following results:—

	Grs. of sugar.		Brewer's libs.
Alcohol, 22¾ grs., equal to - - - -	42·2	or	16·
Acetic acid, 3 grs. - - - - -	5·		1·9
Spent wash, of sp. grav. 1·016 - - - -			5·76
Total weight - -			23·66

It might be thought that the proper kind of sugar to select in this instance, as the representative of alcohol and acetic acid, should be grape sugar, whose atomic weight is 180; but it has long ago been shown by Dr. Ure, that the kind of sugar actually employed in the construction of our saccharometer tables must have been cane sugar, the atom of which is 171; and hence the reason why it must be employed in this calculation.

We may now turn our attention to the business of the distiller, which is a kind of supplementary operation to that of the brewer. There are, however, some important differences, both in mashing and fermenting, between these two methods of producing alcohol; for the principal object of the brewer is to secure flavour and transparency to the fermented product, whilst the sole care of the distiller is to ensure the complete alcoholisation of all the saccharine and gummy constituents of this wort. We have seen that to the brewer the presence of dextrine was essential; whereas, in distillation, the more purely saccharine the wort the better. On this account, although malt is much dearer than raw grain, many eminent distillers continue to employ it alone, from the simple circumstance that its relatively large contents of diastase furnishes, in the limited period assigned for mashing, an infinitely more saccharine wort than can be produced in the same space of time from a mixture of one part of malt and seven or eight of barley meal. Nevertheless by maintaining the wort from the latter at a sufficient temperature for a few hours, as indicated with respect to beer-wort, the diastase in it would exert its specific action upon the dextrine, and, in the end, give as saccharine a wort from mixed grain as from pure malt. This subject is peculiarly worthy of the attention of distillers; for the sluggish fermentative qualities of dextrine are such, that very frequently a considerable quantity of this substance remains in the wash unacted on, and passes away with the residue as a waste product. It is, indeed, customary for the distiller to seek a remedy for this, in the employment of large and frequently repeated additions of yeast; and there can be no doubt as to the propriety of this measure. Still, however, the true solution of this difficulty must be referred to a period anterior to fermentation, and it is in the under-back where it should be grappled with and vanquished.

If we examine with care the catalytic effect of diastase upon starch, we shall find that the time employed by the distiller is far too short to achieve the object which it is his interest to bring about. In the case of the brewer, many conditions, as we have pointed out, require to be foreseen and provided for; and hence a uniform system of mashing is to be condemned in brewing; but the distiller has only one single circumstance to bear in mind, and that is, if possible, the total conversion of all the hordeine, starch, dextrine, and other constituents of his grain and wort into sugar. In fact, he can scarcely by any chance mash too long or keep his wort at 170° for too many hours;—at all events, the following observations demonstrate that the time now employed is barely one-fourth of that necessary for success, under the most favourable circumstances:—A mixture, composed of 1 part of very fine malt and 7 parts of barley-meal, was mashed with great care in a vessel capable of having its temperature kept at any required degree for many consecutive hours. The heat of the water was 180°; and it was found, after thorough mixing, that this had fallen to 168°, at which point it was accordingly decided to maintain it, and a series of experimental essays were made upon each sample of the wort, with the view of illustrating the progressive formation of sugar. The results were as follows:—

	Sugar.	Dextrine.
2 hours after mashing - - - - -	1·3	18·7
3 ditto ditto - - - - -	4·1	15·9
4 ditto ditto - - - - -	6·3	13·7
5 ditto ditto - - - - -	8·	12·
6 ditto ditto - - - - -	9·2	10·8
7 ditto ditto - - - - -	10·7	9·3
8 ditto ditto - - - - -	12·	8·
9 ditto ditto - - - - -	13·3	6·7
10 ditto ditto - - -	14·5	5·5
11 ditto ditto - - -	15·7	4·3
12 ditto ditto - - - - -	16·9	3·1

Hence, instead of three hours, which is the period commonly used for mashing, the distiller would be warranted in continuing this operation for twelve hours. In reality, however, it is only the wort which requires this treatment; for, after the third hour, all the starch and nearly the whole of the hordeine have become soluble, and nothing but continued heat is required to complete the saccharification of the wort. The working of the mash-tun need not therefore be varied, as it will suffice to maintain the under-back for 6 or 8 hours at a temperature of 170°. The advantage of converting all the dextrine into sugar is not limited to the mere saving of material, or the production of more alcohol, for there is another and most important object gained. Sugar ferments more freely and at a lower temperature than dextrine, consequently the heat of the fermenting vat need never rise so high, nor require the large quantity of yeast now employed for the purpose of forcing a rapid and hot fermentation. Thus the tendency to generate fusel oil would be destroyed, as there is not the slightest doubt that the formation of this oil is due to an excess of temperature in the fermenting-vat,

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and constantly bears a relation to the amount of dextrine in the wort; for this, as we have before stated, necessitates the employment of a higher fermenting heat than sugar, by which the elements of the decomposing materials take on new and unusual arrangements. The presence of fusel oil in spirit is a serious impediment to the distiller, and either retards the sale of his produce, or diminishes its value in the market.

As usual, the Excise regulations interfere much with the progress of this, as of every other manufacture under fiscal superintendence. Careful to prevent fraud, they cripple industry, and seek, as it were, to secure the honesty of the labourer by cutting off his hand:—ignorant or careless, meanwhile, of the permanent mischief which they inflict. Yet, we know of no more fitting subject for fiscal burdens, than the manufacture of ardent spirits; and had Excise interference been limited to this branch of industry, we should have deemed it a matter for congratulation, rather than otherwise. Nevertheless, consistency is a kind of virtue in politics; and we cannot imagine why the quasi superior, moral, and intellectual status of Ireland is continually tempted to err, by a low duty of but 2*s.* 8*d.* per gallon, whilst nearly three times this amount is needed to repress the bad habits of the people of England. The duty now charged is, for England 7*s.* 10*d.*, for Scotland 3*s.* 8*d.*, and for Ireland 2*s.* 8*d.* per gallon of proof spirits: but on what principle this graduated scale of temptation to drunkenness has been so fixed, we are quite unable to conceive. To return, however, to the question of distillation, the duty can be charged the distiller in any one of three ways, viz. according to the gravity of the wort he uses: the attenuation of that wort by fermentation; or lastly, the actual quantity of spirit which he produces; the latter being, of course, the only just mode of charge. The restrictions and penalties are excessive, as our courts of law too frequently testify; and the notorious prevalence of smuggling seems to prove that the present rates of duty are too high, and offer a premium for fraud greater than the terror of a temporary imprisonment. The greatest improvement in modern times, as regards distillation, is that brought about by the invention of the apparatus, now well known under the name of "Coffey's still." It would be foreign to our task to give a minute description of this contrivance here (see STILL); its principle is similar to that of the "cascade chimique" of Clement Desormes. The wort, or other fluid to be distilled, is made to flow over a very extensive surface in contact with a current of steam passing in an opposite direction; by which means the steam is condensed, and giving up its latent heat to the more volatile spirit, this latter is driven on into the condenser in a state of great purity; whilst the residuary wort and the condensed steam flow out of the vessel from beneath in a continual stream. Mr. Coffey had many impediments to contend with, from the opposition of the Excise authorities, in his first attempt to introduce this ingenious invention into public use; but prejudice and ignorance have at length given way, and the Coffey's still may be now seen in operation at almost every large distillery in the kingdom. After the distiller has paid duty on the spirit which he has manufactured, it is transmitted to the rectifier, whose premises must be at a considerable distance from the distillery, according to act of parliament. The business of the rectifier is to purify the spirit by separating its fusel oil; and this he commonly effects through the agency of caustic potash. The impure spirit being mixed with a portion of potash, and carbonate of potash, is carefully distilled or rectified, until it ceases to possess any disagreeable odour, when it is again distilled in contact with certain aromatic substances, to give it the requisite qualities of the particular spirit or liquor desired. There is, however, too much reason to fear that the necessary measures of purification are neglected in the case of common gin,—the defect being merely covered or concealed beneath more powerful odours. This practice cannot be too strongly reprobated; for experiments made purposely on dogs have convinced us that fusel oil is a highly poisonous substance, and possesses acro-narcotic powers of no ordinary energy. Its removal from an article of universal consumption, like spirits, ought therefore to be deemed an important subject for sanitary legislation, and not left to the casual skill or dubious honesty of any class of manufacturers whatever. There is more or less fusel oil in all the gin we have examined.

BRICK. (*Brique*, Fr.; *Backsteine*, *ziegelsteine*, Germ.) A solid, commonly rectangular, composed of clay hardened by heat, and intended for building purposes. The natural mixture of clay and sand, called *loam*, as well as marl, which consists of lime and clay, with little or no sand, constitutes also a good material for making bricks. The poorer the marl is in lime, the worse adapted it is for agricultural purposes, and the better for the brick manufacturer, being less liable to fuse in his kiln. When a natural compound of silica and clay can be got nearly free from lime and magnesia, it forms a kind of bricks very refractory in the furnace, hence termed *fire-bricks*. Such a material is the slate-clay, *schieferthon*, of our coal measures, found abundantly, and of excellent quality, at Stourbridge, and in the neighbourhood of Newcastle and Glasgow. The London brick-makers add to the clay about one-third of coal ashes obtained from the kitchen dust-holes; so that when the bricks are put into the kiln, the quantity of

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coaly matter attached to their surface serves to economise fuel, and makes them less apt to shrink in the fire; though they are less compact, and probably less durable than the bricks made in the coal districts of England.

The general process of brick-making consists in digging up the clay in autumn; exposing it, during the whole winter, to the frost, and the action of the air, turning it repeatedly, and working it with the spade; breaking down the clay lumps in spring, throwing them into shallow pits, to be watered and soaked for several days. The next step is to temper the clay, which is generally done by the treading of men or oxen. In the neighbourhood of London, however, this process is performed in a horse-mill. The kneading of the clay is, in fact, the most laborious but indispensable part of the whole business; and that on which, in a great measure, the quality of the bricks depends. All the stones, particularly the ferruginous, calcareous, and pyritous kinds, should be removed, and the clay worked into a homogeneous paste with as little water as possible.

The earth, being sufficiently kneaded, is brought to the bench of the moulder, who works the clay into a mould made of wood or iron, and strikes off the superfluous matter. The bricks are next delivered from the mould, and ranged on the ground; and when they have acquired sufficient firmness to bear handling, they are dressed with a knife, and staked or built up in long dwarf walls, thatched over, and left to dry. An able workman will make, by hand, 5000 bricks in a day.

The different kinds of bricks made in England are principally *place bricks, gray and red stocks, marl facing bricks,* and *cutting bricks.* The place bricks and stocks are used in common walling. The marls are made in the neighbourhood of London, and used in the outside of buildings; they are very beautiful bricks, of a fine yellow colour, hard, and well burnt, and, in every respect, superior to the stocks. The finest kind of marl and red bricks, called cutting bricks, are used in the arches over windows and doors, being rubbed to a centre, and gauged to a height.

In France attempts were long ago made to substitute animals and machines for the treading of men's feet in the clay kneading pit; but it was found that their schemes could not replace, with advantage, human labour where it is so cheap, particularly for separating the stones and heterogeneous matter from the loam. The more it is worked, the denser, more uniform, and more durable, the bricks which are made of it. A good French workman, in a day's labour of 12 or 13 hours, it has been said, is able to mould from 9000 to 10,000 bricks, 9 inches long, 4½ inches broad, and 2¼ thick; but he must have good assistants under him. In many brickworks near Paris, screw-presses are now used for consolidating the bricks and paving tiles in their moulds. M. Mollerat employed the hydraulic press for the purpose of condensing pulverized clay, which, after baking, formed beautiful bricks; but the process was too tedious and costly. An ingenious contrivance for moulding bricks mechanically, is said to be employed near Washington, in America. This machine moulds 30,000 in a day's work of 12 hours, with the help of one horse, yoked to a gin wheel, and the bricks are so dry when discharged from their moulds, as to be ready for immediate burning. The machine is described, with figures, in the *Bulletin de la Société d'Encouragement* for 1819, p. 361. *See further on, an account of our recent patents.*

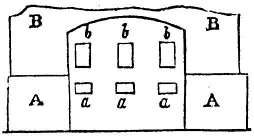
Bricks, in this country, are generally baked either in a clamp or in a kiln. The latter is the preferable method, as less waste arises, less fuel is consumed, and the bricks are sooner burnt. The kiln is usually 13 feet long, by 10½ feet wide, and about 12 feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclining towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice-work; the kiln is then covered with pieces of tiles and bricks, and some wood put in, to dry them with a gentle fire. This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish color to transparent. The mouth or mouths of the kiln are now dammed up with a *shinlog,* which consists of pieces of bricks piled one upon another, and closed with wet brick earth, leaving above it just room sufficient to receive a fagot. The fagots are made of furze, heath, brake, fern, &c., and the kiln is supplied with these until its arches look white, and the fire appears at the top; upon which the fire is slackened for an hour, and the kiln allowed gradually to cool. This heating and cooling is repeated until the bricks be thoroughly burnt, which is generally done in 48 hours. One of these kilns will hold about 20,000 bricks.

Clamps are also in common use. They are made of the bricks themselves, and generally of an oblong form. The foundation is laid with *place brick,* or the driest of those just made, and then the bricks to be burnt are built up, tier upon tier, as high as the clamp is meant to be, with two or three inches of breeze or cinders strewed between each layer of bricks, and the whole covered with a thick stratum of breeze. The fire-place is perpendicular, about three feet high, and generally placed at the west end; and the flues are formed by gathering or arching the bricks over, so as to leave a space between each of nearly a brick wide. The flues run straight through the clamp, and are filled with wood, coals, and breeze, pressed closely together. If the bricks are to be burnt off quickly, which may be done in 20 or 30 days, according as the weather may suit, the flues should be only at about six feet distance; but if there be no immediate hurry, they may be placed nine feet asunder, and the clamp left to burn off slowly.

Floating bricks are a very ancient invention: they are so light as to swim in water; and Pliny tells us, that they were made at Marseilles; at Colento, in Spain; and at Pittane, in Asia. This invention, however, was completely lost, until M. Fabbroni published a discovery of a method to imitate the floating bricks of the ancients. According to Posidonius, these bricks are made of a kind of argillaceous earth, which was employed to clean silver plate. But as it could not be our tripoli, which is too heavy to float in water, M. Fabbroni tried several experiments with mineral argaric, guhr, lac-lunæ, and fossil meal, which last was found to be the very substance of which he was in search. This earth is abundant in Tuscany, and is found near Casteldelpiano, in the territories of Sienna. According to the analysis of M. Fabbroni, it consists of 55 parts of silicious earth, 15 of magnesia, 14 of water, 12 of alumina, 3 of lime, and 1 of iron. It exhales an argillaceous odor, and, when sprinkled with water, throws out a light whitish smoke. It is infusible in the fire; and, though it loses about an eighth part of its weight, its bulk is scarcely diminished. Bricks composed of this substance, either baked or unbaked, float in water; and a twentieth part of clay may be added to their composition without taking away their property of swimming. These bricks resist water, unite perfectly with lime, are subject to no alteration from heat or cold, and the baked differ from the unbaked only in the sonorous quality which they have acquired from the fire. Their strength is little inferior to that of common bricks, but much greater in proportion to their weight; for M. Fabbroni found, that a floating brick, measuring 7 inches in length, 4½ in breadth, and one inch eight lines in thickness, weighed only 14¼ ounces; whereas a common brick weighed 5 pounds 6¾ ounces. The use of these bricks may be very important in the construction of powder magazines and reverberatory furnaces, as they are such bad conductors of heat, that one end may be made red hot while the other is held in the hand. They may also be employed for buildings that require to be light; such as cooking-places in ships, and floating batteries, the parapets of which would be proof against red-hot bullets.

The following plan of a furnace or kiln for burning tiles has been found very convenient:—

Fig. 198., front view, A A, B B, the solid walls of the furnace; *a a a*, openings to the ash-pit, and the draught hole; *b b b*, openings for the supply of fuel, furnished with a sheet-iron door. *Fig.* 199. Plan of the ash-pits and air channels C C C. The principal branch of the ash-pit D D D, is also the opening for taking out the tiles, after removing the grate; E, the smoke flue. *Fig.* 200. Plan of the kiln seen from above. The grates H H H. The tiles to be fired are arranged upon the spaces *f f f f*.



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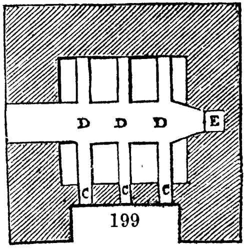

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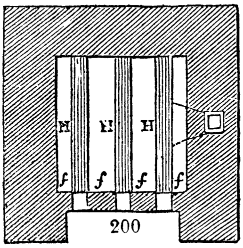

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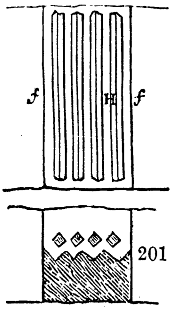
Fig. 201. is the plan and section of one of the grates upon a much larger scale than in the preceding figures.



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Mechanical brick moulding.—Messrs. Lyne and Stainford obtained in August, 1825, a patent for a machine for making a considerable number of bricks at one operation. It consists, in the first place, of a cylindrical pug-mill of the kind usually employed for comminuting clay for bricks and tiles, furnished with rotatory knives, or cutters, for breaking the lumps and mixing the clay with the other materials of which bricks are commonly made. Secondly, of two movable moulds, in each of which fifteen bricks are made at once; these moulds being made to travel to and fro in the machine for the purpose of being alternately brought under the pug-mill to be fitted with the clay, and then removed to situations where plungers are enabled to act upon them. Thirdly, in a contrivance by which the plungers are made to descend, for the purpose of compressing the material and discharging it from the mould in the form of bricks. Fourthly, in the method of constructing and working trucks which carry the receiving boards, and conduct the bricks away as they are formed.

Fig. 202. exhibits the general construction of the apparatus; both ends of which being exactly similar, little more than half of the machine is represented. *a* is the cylindrical pug-mill, shown partly in section, which is supplied with the clay and other

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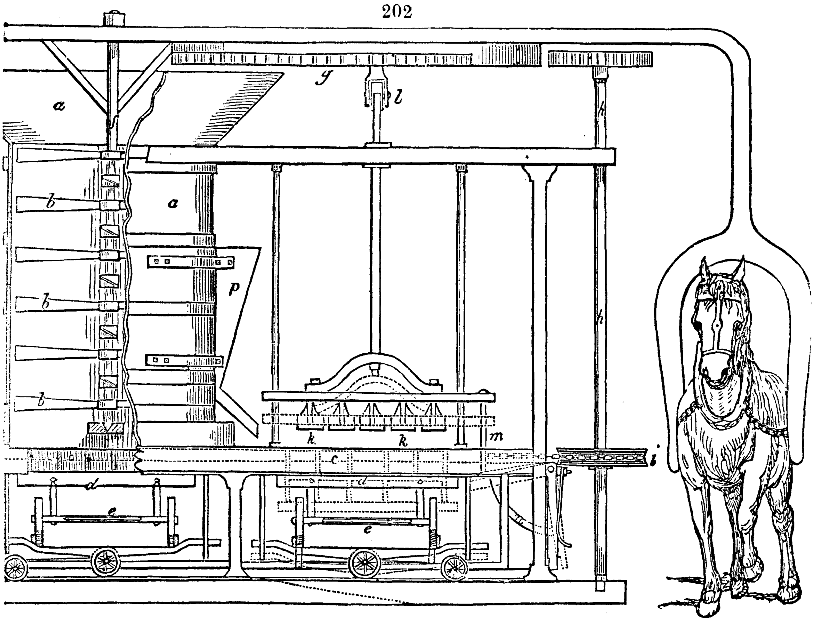

materials from a hopper above; *b b*, are the rotatory knives or cutters, which are attached to the vertical shaft, and, being placed obliquely, press the clay down towards the bottom of the cylinder, in the act of breaking and mixing it as the shaft revolves. The lower part of the cylinder is open; and immediately under it the mould is placed in which the bricks are to be formed. These moulds run to and fro upon ledges in the side frames of the machine; one of the moulds only can be shown by dots in the figure, the side rail intervening; they are situated at *c c*, and are formed of bars of iron crossing each other, and encompassed with a frame. The mould resembles an ordinary sash window in its form, being divided into rectangular compartments (fifteen are proposed in each) of the dimensions of the intended bricks, but sufficiently deep to allow the material, after being considerably pressed in the mould, to leave it, when discharged, of the usual thickness of a common brick.

The mould being open at top and bottom, the material is allowed to pass into it, when situated exactly under the cylinder; and the lower side of the mould, when so placed, is to be closed by a flat board *d*, supported by the trunk *e*, which is raised by a lever and roller beneath, running upon a plane rail with inclined ends.

The central shaft, *f*, is kept in continual rotatory motion, by the revolution of the upper horizontal wheel *g*, of which it is the axis; and this wheel may be turned by a horse yoked to a radiating arm, or by any other means. A part of the circumference of the wheel *g*, has teeth which are intended at certain periods of its revolution to take into a toothed pinion, fixed upon the top of a vertical shaft *h h*. At the lower part of this vertical shaft, there is a pulley *i*, over which a chain is passed that is connected to the two moulds *c*, and to the frame in which the trucks are supported; by the rotation of the vertical shaft, the pulley winds a chain, and draws the moulds and truck frames along.

The clay and other material having been forced down from the cylinder into the mould, the teeth of the horizontal wheel *g* now come into geer with the pinion upon *h*, and turn it and the shaft and pulley *i*, by which the chain is wound, and the mould at the right hand of the machine brought into the situation shown in the figure; a scraper or edge-bar under the pug-mill having levelled the upper face of the clay in the mould, and the board *d*, supported by the truck *e*, formed the flat under side.

The mould being brought into this position, it is now necessary to compress the materials, which is done by the descent of the plungers *k k*. A friction-roller *l*, pendant from the under side of the horizontal wheel, as that wheel revolves, comes in contact with an inclined plane, at the top of the shaft of the plungers; and, as the friction-roller passes over this inclined plane, the plungers are made to descend into the mould, and to compress the material; the resistance of the board beneath causing the clay to be squeezed into a compact state. When this has been effectually accomplished, the further descent of the plungers brings a pin *m*, against the upper end of a quadrant catch-lever *n*, and, by depressing this quadrant, causes the balance-lever upon which the truck is now supported to rise at that end, and to allow the truck with the board *d* to descend, as shown by dots; the plungers at the same time forcing out the bricks from the moulds, whereby they are deposited upon the board *d*; when, by drawing the truck forward out of the machine, the board with the bricks may be removed and replaced by another board. The truck may then be again introduced into the machine, ready to receive the next parcel of bricks.

By the time that the discharge of the bricks from this mould has been effected, the other mould under the pug cylinder has become filled with the clay, when the teeth of the horizontal wheel coming round, take into a pinion upon the top of a vertical shaft, exactly similar to that at *h*, but at the reverse end of the machine, and cause the moulds and the frame supporting the trucks to be slidden to the left end of the machine; the upper surface of the mould being scraped level in its progress, in the way already described. This movement brings the friction-wheel *o*, up the inclined plane, and thereby raises the truck, with the board to the under side of the mould, ready to receive another supply of clay ; and the mould at the left hand side of the machine being now in its proper situation under the plungers, the clay becomes compressed, and the bricks discharged from the mould in the way described in the former instance ; when this truck being drawn out, the bricks are removed to be dried and baked, and another board is placed in the same situation. There are boxes, *p*, upon each side of the pug cylinder containing sand, at the lower parts of which small sliders are to be opened (by contrivances not shown in the figure) as the mould passes under them, for the purpose of scattering sand upon the clay in the mould to prevent its adhering to the plungers. There is also a rack and toothed sector, with a balance-weight connected to the inclined plane at the top of the plunger-rods, for the purpose of raising the plunger after the friction-roller has passed over it. And there is a spring acting against the back of the quadrant-catch for the purpose of throwing it into its former situation, after the pin of the plunger has risen.

One of the latest, and apparently most effective machines for brick-making, is that patented by Mr. Edward Jones, of Birmingham, in August, 1835. His improvements are described under four heads; the first applies to a machine for moulding the earth into bricks in a circular frame-plate horizontally, containing a series of moulds or rectangular boxes, standing radially round the circumference of the circular frame, into which boxes successively the clay is expressed from a stationary hopper as the frame revolves, and after being so formed, the bricks are successively pushed out of their boxes, each by a piston, acted upon by an inclined plane below. The second head of the specification describes a rectangular horizontal frame, having a series of moulding boxes placed in a straight range, which are acted upon for pressing the clay by a corresponding range of pistons fixed in a horizontal frame, worked up and down by rods extending from a rotatory crank shaft, the moulding boxes being allowed to rise for the purpose of enabling the pistons to force out the bricks when moulded, and leave them upon the bed or board below. The third head applies particularly to the making of tiles, for the flooring of kilns in which malt or grain is to be dried. There is in this contrivance a rectangular mould, with pointed pieces standing up for the purpose of producing air-holes through the tiles as they are moulded, which is done by pressing the clay into the moulds upon the points, and scraping off the superfluous matter at top by hand. The fourth or last head applies to moulding chimney pots in double moulds, which take to pieces for the purpose of withdrawing the pot when the edges of the slabs or sides are sufficiently brought into contact.

"The drawing which accompanies the specification very imperfectly represents some parts of the apparatus, and the description is still more defective; but as we are acquainted with the machinery, we will endeavor to give it an intelligible form, and quote those parts of the specification which point the particular features of novelty proposed to be claimed by the patentee as his invention, under the several heads." *

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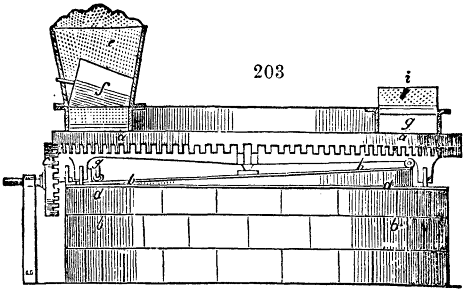
* Mr Newton, in his London Journal, February, 1837.

203



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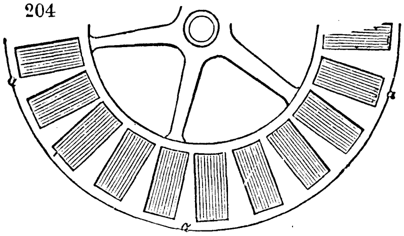

Fig. 203 represents, in elevation, the first-mentioned machine for moulding bricks. The moulds are formed in the face of a circular plate or wheel, *a a*, a portion of the upper surface of which is represented in the horizontal view, *fig.* 204. Any convenient number of these moulds are set radially in the wheel, which is mounted upon a central pivot, supported by the masonry *b b*. There is a rim of teeth round the outer edge of the wheel *a a*, which take into a pinion *c*, on a shaft connected to the first mover, and by these means the wheel *a*, with the moulding boxes, is made to revolve horizontally guided by arms with anti friction rollers, which run round a horizontal plate *a a*, fixed upon the masonry.

A hopper, *e*, filled with the brick earth shown with one of the moulding boxes in section, is fixed above the face of the wheel in such a way that the earth may descend from the hopper into the several moulding boxes as the wheel passes round under it; the earth being pressed into the moulds, and its surface scraped off smooth by a conical roller *f*, in the bottom of the hopper.

Through the bottom of each moulding box there is a hole for the passage of a piston rod *g*, the upper end of which rod carries a piston with a wooden pallet upon it, acting within the moulding box; and the lower end of this rod has a small anti-friction roller, which, as the wheel *a* revolves, runs round upon the face of an oblique ring or inclined way, *h h*, fixed upon the masonry.

The clay is introduced into the moulding boxes from the hopper, fixed over the lowest part of the inclined way *h*, and it will be perceived that as the wheel revolves, the piston rods *g*, in passing up the inclined way, will cause the pistons to force the new-moulded bricks, with their pallet or board under them, severally up the mould, into the situation shown at *i*, in *fig.* 203, from whence they are to be removed by hand. Fresh pallets being then placed upon the several pistons, they, with the moulds, will be ready for moulding fresh bricks, when, by the rotation of the wheel *a*, they are severally brought under the hopper, the pistons having sunk to the bottoms of their boxes, as the piston rods passed down the other side of the inclined way *h*.

The patentee says, after having described the first head of his invention, he would have it understood that the same may be varied without departing from the main object of the invention; viz., that of arranging a series of moulds when worked by means of an inclined track, and in such manner that bricks, tiles, or other articles made of brick earth, may be capable of being formed in a mould with pallets or boards laid within the moulds, and constituting the bottom thereof, the bricks being removed from out of the moulds, with the pallets or boards under them, as above described. "I do not, therefore, confine myself to the precise arrangement of the machine here shown, though it is the best with which I am acquainted for the purpose."

The second head of the invention is another construction of apparatus for moulding bricks, in this instance, in a rectangular frame. *Fig.* 205 is a front elevation of the machine; *fig.* 206, a section of the same taken transversely. *a a* is the standard frame-work and bed on which the bricks are to be moulded. Near the corners of this standard frame-work, four vertical pillars *b b* are erected, upon which pillars the frame of the moulding boxes *c*, slides up and down, and also the bar *d*, carrying the rods of the pistons *e e e*. These pistons are for the purpose of compressing the clay in the moulding box, and therefore must stand exactly over and correspond with the respective moulds in the frame *c* beneath.

The sliding frame *c*, constituting the sides and ends of the moulding boxes, is supported at each end by an upright sliding rod *f*, which rods pass through guides fixed to the sides of the standard frame *a a*, and at the lower end of each there is a roller, bearing upon the levers *g*, on each side of the machine, but seen only in *fig.* 206, which levers when depressed, allow the moulding boxes to descend, and rest upon the bed or table of the machine *h h*.

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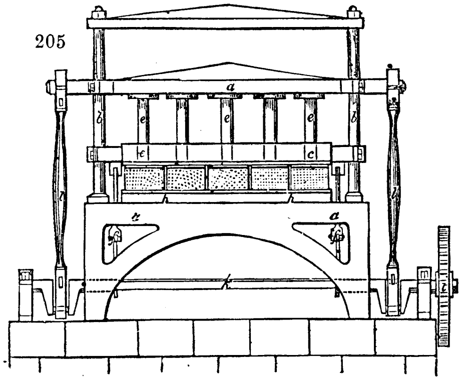

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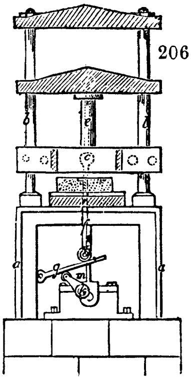

In this position of the machine resting upon the bed or table, the brick-earth is to be placed upon, and spread over, the top of the frame *c*, by the hands of workmen, when the descent of the plunger or pistons *e e e*, will cause the earth to be forced into the moulds, and the bricks to be formed therein. To effect this, rotatory power is to be applied to the toothed wheel *i*, fixed on the end of the main driving crank shaft *k k*, which on revolving will, by means of the crank rods *l l*, bring down the bar *a*, with the pistons or plungers *e e e*, and compress the earth compactly into the moulds, and thereby form the bricks.

When this has been done, the bricks are to be released from the moulds by the moulding frame *c* rising up from the bed, as shown in *fig.* 205., the pistons still remaining depressed, and bearing upon the upper surfaces of the bricks. The moulding frame is raised by means of cams *m*, upon the crank shaft, which at this part of the operation are brought under the levers *g*, for the purpose of raising the cams and the sliding rods *f*, into the position shown in *fig.* 206.

The bricks having been thus formed and released from their moulds, they are to be removed from the bed of the machine by pushing forward, on the front side, fresh boards or pallets, which of course will drive the bricks out upon the other side, whence they are to be removed by hand.

There is to be a small hole in the centre of each pallet, and also in the bed, for the purpose of allowing any superfluous earth to be pressed through the moulding boxes when the pistons descend. And in order to cut off the projecting piece of clay which would be thus formed on the bottom of the brick, a knife-edge is in some way connected to the bed of the machine; and as the brick slides over it, the knife separates the protuberant lump; but the particular construction of this part of the apparatus is considered to be of little importance; and the manner of effecting the object is not clearly stated in the specification.

The patentee proposes a variation in this construction, which he describes in these words: "It will be evident that in place of having the moulds to rise, they may, by suitable arrangements, be made to descend below the bricks. In this case, in place of the boards, stationary blocks to receive the pallets must be fixed on the bed of the machine, and these blocks must be shaped in such a manner as to allow of the moulds passing over them: and then it will be desirable to use the first part of my improvements, that of having the pallets within the moulds at the time of moulding the bricks; or in case of working with exceedingly stiff brick-earth, the pallets may be dispensed with." In 1849, 1,503,961,106 bricks paid duty in the United Kingdom; the revenue from which was 461,582*l.* 6*s.* 1*d.*

BRICKS. Mr. F. W. Simms, C. E., communicated to the Institution of Civil Engineers, in April and May, 1843, an account of the process of brick-making for the Dover railway. The plan adopted is called slop-moulding, because the mould is dipped into water before receiving the clay, instead of being sanded as in making sand-stock bricks. The workman throws the proper lump of clay with some force into the mould, presses it down with his hands to fill the cavities, and then strikes off the surplus clay with a stick. An attendant boy, who has previously placed another mould in a water trough by the side of the moulding table, takes the mould just filled, and carries it to the floor, where he carefully drops the brick from the mould on its flat side, and leaves it to dry; by the time he has returned to the moulding table, and deposited the empty mould in the water trough, the brickmaker will have filled the other mould, for the boy to convey to the floor, where they are allowed to dry, and are then stacked in readiness for being burned in clamps or kilns. The average product is shown in the following table:—

Force employed.	Area of land.		Duration of season	Produce per week.	Produce per season.
	Roods.	Perches.	Weeks.	Bricks.	Bricks.
1 moulder 1 temperer 1 wheeler 1 carrier boy 1 picker boy	2	$14\frac{1}{2}$	22	16,100	354,200

It appears that while the produce in sand-stock bricks is to that of slop-bricks in the same time as 30 to 16, the amount of labor is as 7 to 4; while the quantity of land, and the cost of labor per thousand, is nearly the same in both processes. The quantity of coal consumed in the kiln was at the rate of 10 cwt. 8lbs. per thousand bricks. The cost of the bricks was 2*l.* 1*s.* 6*d.* per thousand. The slop-made bricks are fully 1 pound heavier than the sand-stock. Mr. Bennett stated to the meeting, that at his brick-field at Cowley, the average number of sand-stock bricks moulded was 32,000; but that frequently so many as 37,000, or even 50,000, were formed. The total amount in the shrinkage of his bricks was $\frac{13}{16}$ of an inch upon 10 inches in length; but this differed with the different clays. Mr. Simms objected to the use of machinery in brick-making, because it caused economy only in the moulding, which constituted no more than about one eighth of the total expense.

The principal varieties of bricks are called *malm*, *paviors*, *stocks*, *grizzles*, *places*, and *shuffs*. For the first and best kind, the clay was washed and selected with care; stocks were good enough for ordinary building purposes; the rest are inferior. The difference in price between malms, paviors, and stocks, was 15*s.* or 20*s.* per 1,000; between stocks and places, 10*s.* The average weight of a sand-stock brick is fully 5 pounds, that of a slop is 1 pound more.

I believe that the siliceous sand on the surface of the sand-stocks is useful in favoring adhesion of mortar, by the production of a silicate of lime. To smooth aluminous bricks, mortar sometimes forms no stony adhesion.

Mr. Prosser, of Birmingham, makes bricks by pressure. The clay is first ground upon a slip kiln, as if for making pottery, then ground to a fine powder, and in that dry state it is subjected to the heavy pressure of about 250 tons, in strong metal moulds, by which means it is reduced to about one third of its original thickness. The clay seems to have retained sufficient moisture to give it cohesion, and the tiles are perfectly sharp at the edges. They being then baked within seggars by the heat of a kiln, seldom crack in the baking. The bricks thus formed are denser than usual, and weigh $6\frac{3}{4}$ lbs., with a specific gravity of 2·5.

Fig. 207., represents Mr. Hunt's brick-making machine. The principal working parts consist of 2 cylinders, each covered by an endless web, and so placed as to form the front and back of a hopper, the two sides being iron plates, placed so that when the hopper is filled with tempered clay from the pug-mill, the lower part of the hopper, and consequently the mass of clay within it, has exactly the dimensions of a brick. Beneath the hopper an endless chain traverses simultaneously with the movement of the cylinders. The pallet-boards are laid at given intervals upon the chain, and being thus placed under the hopper, while the clay is brought down with a slight pressure, a frame with a wire stretched across it is projected throug the

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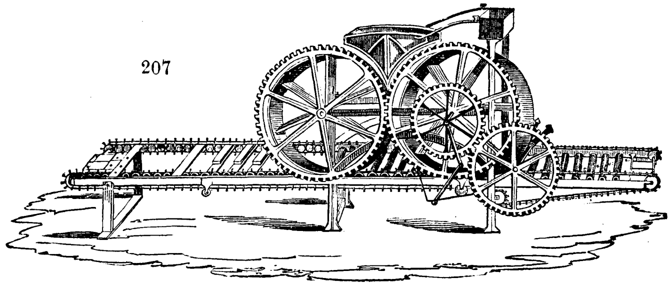
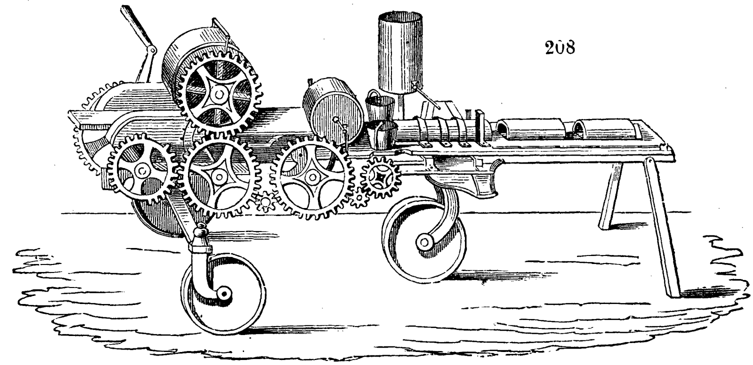


mass of clay, cutting off exactly the thickness of the brick, which is removed at the same moment by the forward movement of the endless chain. This operation is repeated each time that a pallet-board comes under the hopper.

The chief object of this machine, which is worked by hand, is to produce good square compact bricks of uniform quality, using only a slight pressure. It has been found to be very difficult to dry bricks made by machinery, where a considerable pressure has been employed, because, before the evaporation from the centre of the clay is completed, the surfaces have become hard and peel off. The present machine is in operation in several parts of England, producing usually about 1200 bricks per hour, while each machine requires only 2 men and 3 boys to tend it, and to take off the bricks. The clot-moulders are dispensed with, and the workmen are common labourers, so that professed brick-makers at higher wages are not needed.

Fig. 208. shows Mr. Hunt's machine for making tiles, and it is on the same principle. It consists of two iron cylinders, round which webs or bands of cloth revolve, whereby the clay is pressed into a slab of uniform thickness, without adhering to the cylinders. It is then carried over a covered wheel, curved on the rim, which gives the tile the semi-cylindrical or other required form; after which the tiles are polished and finished by passing through three iron moulds of a horse-shoe form, as shown in the centre of the cut, while they are at the same time moistened from a water cylinder placed above them. The tiles are next cut off to such lengths as are wanted, and carried away by an endless web, whence they are transferred by boys to the drying shelves.



208

Flat tiles, for sole pieces to draining tiles, are formed in nearly the same manner, being divided into two portions while passing through the moulds; the quantity of clay used for one draining tile being as much as for two soles.

The method of making bricks in the vicinity of London differed from that of almost all other places, because the material there employed is not pure clay, but a loam of a slightly cohesive nature, which will not admit of its being used in the natural state and burned in close kilns with coal; but with an admixture of ashes it becomes sufficiently tenacious to be formed into bricks, by inducing a slight semi-fusion. But the coal-ashes are also of advantage in the process of burning, because they enable the fire to spread gradually from the lower tiers, through the whole mass in the kiln or clamp, and thus obviate the effect of an intense partial heat, where distinct coal fires are trusted to alone, whereby the bricks nearest it get vitrified and glazed.

The brick kilns and clamps round London, and other large cities, which are fired with the breeze-rubbish collected from dust holes, that contain the refuse of kitchens, &c., emit, in consequence, most unpleasant effluvia; but brick-kilns fired with clean coke or coals, give out no gases of a more noxious nature than common household fires. The consideration of this subject was closely pressed upon my attention on being consulted concerning an injunction issued by the chancellor against a brick clamp in the Isle of Wight, fired with clean coke cinders from the steam-engine furnace at Portsmouth Dock Yard. The bricks being of the description called sand-stock, were of course made in moulds very slightly dusted with sand, to make them fall freely out. The sand was brought from Portsmouth harbor, and on being subjected to a degree of heat, more intense certainly than it would suffer in the clamp, was discovered by two chemical witnesses to give out traces of hydrochloric acid. Not content with this trivial indication, the said chemists, in their evidence before the courts of law, paraded a train of goblin gases, as the probable products of the pre-adjudicated clamp.

As it is well known to the chemist that common salt strongly ignited in contact with moist sand will emit hydrochloric acid, there was nothing remarkable in the above observation, but I ascertained that the sand with which the moulds were strewed would give out no hydrochloric acid, at a heat equal at least to what the bricks were exposed to in a clamp 10 or 12 feet high, and fired at its bottom only with a layer of cinders 3 or 4 inches thick. But I further demonstrated that the entire substance of the brick with its scanty film of sand, on being exposed to ignition in a suitable apparatus, gave out—not hydrochloric or any other corrosive acid, but ammonia gas. Hence, the allegations that the clamp set forth a host of acid gases to blight the neighbouring trees, were shown to be utterly groundless; on the contrary, the ammonia evolved from the heated clay would act beneficially upon vegetation, while it was too small in quantity to annoy any human being. A few yards to leeward of a similar clamp, in full activity, I could perceive no offensive odour. All ferruginous clay, when exposed to the atmosphere, absorbs ammonia from it, and of course emits it again on being gently ignited. It is a reproach to science when, as in the above case, it lends itself to judicial prejudice and oppression.

Messrs. Whalley and Lighloller have patented apparatus for manufacturing bricks and tiles, which combines the pug mill, pressing cylinder, screens and die-plate all in one machine; thereby effecting great economy in time and labour, and also in the cost of the machinery itself. The combination alone is claimed.

BRIMSTONE. (*Soufre*, Fr.; *Schwefel*, Germ.) Sulphur, which see.

BRITANNIA TUBULAR BRIDGE (*opening of the*). The opening of this magnificent structure, looked forward to with so much interest, came off on the 5th of March, 1849, at dawn with the grandest success. At precisely seven o'clock, the adventurous convoy, progressing at a speed of seven miles an hour, was lost sight of in the recess of the vast iron corridor. Instead of being driven through with a dispatch indicative of a desire on the part of those who manned it to get in and out with the utmost expedition, the locomotives were propelled at a slow and stately pace, with a view of boldly proving by means of a dead weight the calibre of the bridge at every hazard. The total weight of the locomotives was 90 tons. The appearance of the interior of the tube during the experiment was of a novel and remarkable character. The locomotives were brought to a standstill in the centre of each of the great spans, without causing the slightest strain or deflection. The first process, that of going through the tube and returning, occupied altogether 10 minutes. The second experimental convoy that went through consisted of 24 heavily laden waggons filled with huge blocks of Brymbo coal, in all, engines included, an aggregate weight of 300 tons. This was drawn deliberately through, at the rate of from eight to ten miles an hour, the steam working at quarter power. During the passage of this experimental train through the tube, a breathless silence prevailed until the train rushed out exultingly, and with colours flying, on the other side of the tube, when loud acclamations arose, followed at intervals by the rattle of artillery down the Straits. Upon the return, which occupied about seven minutes, similar demonstrations ensued, and during the progress of the train those who stood upon its top to ascertain any possible vibration, reported they could detect no sensible deflection. An ordeal stronger still was then resorted to; a train of 200 tons of coals was allowed to rest with all its weight for two hours in the centre of the Carmarthenshire tube, and at the end of the time, on the load being removed, it was found to have caused a deflection of only four-tenths of an inch. It is remarkable that this amount of deflection is not so much as one half hour of sunshine would produce upon the structure, it being moreover calculated with confidence that the whole bridge might with safety, and without injury to itself, be deflected to the extent of 13 inches. These loads, it is most material to remember, are immensely more than the bridge will ever be called on to bear in the ordinary run of traffic, though the engineers are of opinion that it would support with ease, and without much show of deflection, a dead weight on its centre of 1,000 tons. Twelve miles an hour is the limit of speed at which Mr. Stephenson intends that trains shall at first go through, more particularly as there are sharp curves at the termini of the tube.

The effect of the recent hurricane on the calibre of the tube has proved that its lateral surface strength is sufficient, and far more than sufficient, to resist the strongest wind. It is calculated that, taking the force of the wind at 50 lbs. on the square foot, an excessive supposition, the resistance offered by the bridge would be 300 tons × 2 = 600 tons, which is not two thirds of its own weight. The wind going at 80 miles an hour, the rush of a hurricane would only press in the ratio of 128 tons on the side. It is intended, when both tubes are up, to brace them together with stays, so as to counteract any possible oscillation.

The great work has now been four years in hand, and is nearly complete, while Telford's suspension bridge took eight years.

The floating and actual transference of the tubes have occupied since June last, a short period, when the bulk of the fabric is taken into consideration. Great fears were entertained for its safety during the late gales, from the recollection in this part of the country of the damage done to Telford's suspension bridge.

BRITISH GUM. The trivial name given to starch, altered by a slight calcination in an oven, whereby it assumes the appearance and acquires the properties of gum, being soluble in cold water, and forming in that state a paste well adapted to thicken the colours of the calico printer. See Dextrine and Starch.

BROMINE, one of the archæal elements, which being developed from its combinations at the positive pole of the voltaic circuit, has been therefore deemed to be idio-electro-positive like oxygen and chlorine. It derives its name from its nauseous smell, Βρῶμος, *fœtor.* It occurs in various saline springs on the continent of Europe, in those of Ashby de la Zouche, and some others in England; in the lake Asphaltites, in sponges, in some marine plants, in an ore of zinc, and in the cadmium of Silesia. At ordinary temperatures it is liquid, of a dark brown colour in mass, but of a hyacinth-red in thin layers. Its smell is rank and disagreeable, somewhat like that of chlorine. It has a very caustic taste. Its specific gravity is 2·966. Applied to the skin it colours it deep yellow and corrodes it. One drop put within the bill of a bird suffices to kill it. It combines with oxygen with feeble affinity, forming bromic acid. Its attraction for hydrogen being far more energetic, it forms therewith a strong acid, the hydrobromic.

Bromine dissolves very sparingly in water, but it is very soluble in alcohol and ether. It combines with carbon, phosphorus, sulphur, and chlorine, as well as with most of the metals. From its scarcity it has not hitherto been applied to any purpose in the arts, except photography; but it is supposed to possess powerful discutient effects upon scrofulous and other glandular tumours, whence the waters containing it are prescribed as an internal and external remedy in such forms of disease.

BRONZE. A compound metal consisting of copper and tin, to which sometimes a little zinc and lead are added. This alloy is much harder than copper, and was employed by the ancients to make swords, hatchets, &c., before the method of working iron was generally understood. The art of casting bronze statues may be traced to the most remote antiquity, but it was first brought to a certain degree of refinement by Theodoros and Rœcus of Samos, about 700 years before the Christian era, to whom the invention of modelling is ascribed by Pliny. The ancients were well aware that by alloying copper with tin, a more fusible metal was obtained, that the process of casting was therefore rendered easier, and that the statue was harder and more durable; and yet they frequently made them of copper nearly pure, because they possessed no means of determining the proportions of their alloys, and because by their mode of managing the fire, the copper became refined in the course of melting, as has happened to many founders in our own days. It was during the reign of Alexander that bronze statuary received its greatest extension, when the celebrated artist Lysippus succeeded by new processes of moulding and melting to multiply groups of statues to such a degree that Pliny called him the *mob of Alexander.* Soon afterwards enormous bronze colossuses were made, to the height of towers, of which the isle of Rhodes possessed no less than one hundred. The Roman consul Mutianus found 3,000 bronze statues at Athens, 3,000 at Rhodes, as many at Olympia and at Delphi, although a great number had been previously carried off from the last town.

In forming such statues, the alloy should be capable of flowing readily into all the parts of the mould, however minute; it should be hard, in order to resist accidental blows, be proof against the influence of the weather, and be of such a nature as to acquire that greenish oxidized coat upon the surface which is so much admired in the antique bronzes called *patina antiqua.* The chemical composition of the bronze alloy is a matter therefore of the first moment. The brothers Keller, celebrated founders in the time of Louis XIV., whose *chefs-d'œuvre* are well known, directed their attention towards this point, to which too little importance is attached at the present day. The statue of Desaix in the place Dauphine, and the column in the Place Vendôme, are noted specimens of most defective workmanship from mismanagement of the alloys of which they are composed. On analysing separately specimens taken from the bas-reliefs of the pedestal of this column, from the shaft, and from the capital, it was found that the first contained only 6 per cent. of alloy, and 94 of copper, the second much less, and the third only 0·21. It was therefore obvious that the founder, unskilful in the melting of bronze, had gone on progressively refining his alloy, by the oxidizement of the tin, till he had exhausted the copper, and that he had then worked up the refuse scoriæ in the upper part of the column. The cannons which the government furnished him for casting the monument consisted of—

Copper - - -	89·360
Tin - - -	10·040
Lead - - -	0·102
Silver, zinc, iron, and loss	0·498
	100·000

The moulding of the several bas-reliefs was so ill-executed, that the chiselers employed to repair the faults removed no less than 70 tons of bronze, which was given them, besides 300,000 francs for their work. The statues made by the Kellers at Versailles were found on chemical analysis to consist of—

	No. 1.	No. 2.	No. 3.	The mean.
Copper	91·30	91·68	91·22	91·40
Tin	1·00	2·32	1·78	1·70
Zinc	6·09	4·93	5·57	5·53
Lead	1·61	1·07	1·43	1·37
	100·00	100·00	100·00	100·00

The analysis of the bronze of the statue of Louis XV. was as follows:—

Copper	82·45	Its specific gravity was 8·482
Zinc	10·30	
Tin	4·10	
Lead	3·15	
	100·00	

The alloy most proper for bronze medals which are to be afterward struck, is composed of from 8 to 12 parts of tin, and from 92 to 88 of copper; to which if two or three parts in the hundred of zinc be added, they will make it assume a finer bronze tint. The alloy of the Kellers is famous for this effect. The metal should be subjected to three or four successive stamps of the press, and be softened between each blow by being heated and plunged into cold water.

The bronze of bells or bell metal is composed in 100 parts of copper 78, tin 22. This alloy has a fine compact grain, is very fusible and sonorous. The other metals sometimes added are rather prejudicial, and merely increase the profit of the founders. Some of the English bells consist of 80 copper, 10.1 tin, 5·6 zinc, and 4·3 lead; the latter metal when in such large quantity is apt to cause insolated drops, hurtful to the uniformity of the alloy.

The *tam-tams and cymbals of bronze.*—The Chinese make use of bronze instruments, forged by the hammer, which are very thin, and raised up in the middle; they are called gongs, from the word *tshoung*, which signifies a bell. Klaproth has shown that they contain nothing but copper and tin; in the proportions of 78 of the former metal and 22 of the latter. Their specific gravity is 8·815. This alloy when newly cast is as brittle as glass, but by being plunged at a cherry-red heat into cold water, and confined between two discs of iron to keep it in shape, it becomes tough and malleable. The cymbals consist of 80 parts copper and 20 tin.

Bronze vessels naturally brittle may be made tenacious by the same ingenious process, for which the world is indebted to M. Darcet. Bronze mortars for pounding have their lips tempered in the same way. Ancient warlike weapons of bronze were variously compounded; swords were formed of 87½ copper, and 12½ tin in 100 parts; the springs of balistæ consisted of 97 copper, and 3 tin.

Cannon metal consists of about 90 or 91 copper, and 10 or 9 of tin. From the experiments of Papacino-d'Antony, made at Turin, in 1770, it appears that the most proper alloy for great guns is from 12 to 14 parts of tin to 100 of copper; but the Comte Lamartilliere concluded from his experiments made at Douay, in 1786, that never less than 8, nor more than 11 of tin should be employed in 100 parts of bronze.

Gilt ornaments of bronze.—This kind of bronze should be easy of fusion, and take perfectly the impression of the mould. The alloy of copper and zinc is when fused of a pasty consistence, does not make a sharp cast, is apt to absorb too much amalgam, is liable to crack in cooling, and is too tough or too soft for the chaser or the turner. Were the quantity of zinc increased to make the metal harder, it would lose the yellow color suitable to the gilder. A fourfold combination of copper, zinc, tin, and lead is preferable for making such ornamental bronze articles; and the following proportions are probably the best, as they unite closeness of grain with the other good qualities. Copper 82, zinc 18, tin 3 or 1, lead 1½ or 3. In the alloy which contains most lead, the tenacity is diminished and the density is increased, which is preferable for pieces of small dimensions Another alloy, which is said to require for its gilding only two thirds of the ordinary quantity of gold, has the following composition: copper, 82·257; zinc, 17·481; tin, 0·238; lead, 0·024.

The antique bronze color is given to figures and other objects made from these alloys by the following process:—Two drachms of sal-ammoniac, and half a drachm of salt of sorrel (binoxalate of potash) are to be dissolved in fourteen ounce measures (English) of colorless vinegar. A hair pencil being dipped into this solution, and pressed gently between the fingers, is to be rubbed equally over the clean surface of the object, slightly warmed in the sun or at a stove; and the operation is to be repeated till the wished-for shade is obtained. (See GILDING.)

The bronze founder ought to melt his metals rapidly, in order to prevent the loss of tin, zinc, and lead, by their oxydizement. Reverberatory furnaces have been long used for this operation; the best being of an elliptical form. The furnaces with dome tops are employed by the bell-founders, because their alloy being more fusible, they do not require so intense a heat; but they also would find their advantage in using the most rapid mode of fusion. The surface of the melting metals should be covered with small charcoal, or coke; and when the zinc is added, it should be dexterously thrust to the bottom of the melted copper. Immediately after stirring the melted mass so as to incorporate its ingredients, it should be poured out into the moulds. In general, the metals most easily altered by the fire, as the tin, should be put in last. The cooling should be as quick as possible in the moulds, to prevent the risk of the metals separating from each other in the order of their density, as they are very apt to do. The addition of a little iron, in the form of tin-plate, to bronze, is reckoned to be advantageous.

One part of tin, and two parts of copper (nearly one atom of tin and four of copper, or more exactly, 100 parts of tin, and 215 copper), form the ordinary speculum metal of reflecting telescopes, which is of all the alloys the whitest, the most brilliant, the hardest, and the most brittle. The alloy of 1 part of tin, and 10 of copper (or nearly one atom of the former to eighteen of the latter), is the strongest of the whole series.

Ornamental objects of bronze, after being cast, are commonly laid upon red-hot coals till they take a dull red heat, and are then exposed for some time to the air. The surface is thereby freed from any greasy matter, some portion of the zinc is dissipated, the alloy assumes more of a coppery hue, which prepares for the subsequent gilding. The black tinge which it sometimes gets from the fire may be removed by washing it with a weak acid. It may be made very clean by acting upon it with nitric acid, of specific gravity 1·324, to which a little common salt and soot have been added, the latter being of doubtful utility; after which it must be well washed in water, and dried with rags or saw-dust.

BRONZING is the art of giving to objects of wood, plaster, &c., such a surface as makes them appear as if made of bronze. The term is sometimes extended to signify the production of a metallic appearance of any kind upon such objects. They ought first to be smeared over smoothly with a coat of size or oil varnish, and when nearly dry, the metallic powder made from Dutch foil, gold leaf, mosaic gold, or precipitated copper, is to be applied with a dusting bag, and then rubbed over the surface with a linen pad; or the metallic powders may be mixed with the drying oil beforehand, and then applied with a brush. Sometimes fine copper, or brass filings, or mosaic gold, are mixed previously with some pulverized bone-ash, and then applied in either way. A mixture of these powders with mucilage of gum arabic is used to give paper or wood a bronze appearance. The surface must be afterward burnished. Copper powder precipitated by clean plates of iron, from a solution of nitrate of copper, after being well washed and dried, has been employed in this way, either alone or mixed with pulverized bone-ash. A finish is given to works of this nature by a coat of spirit varnish.

A white metallic appearance is given to plaster figures by rubbing over them an amalgam of equal parts of mercury, bismuth, and tin, and applying a coat of varnish over it. The iron-colored bronzing is given by black lead or plumbago, finely pulverized and washed. Busts and other objects made of cast iron acquire a bronze aspect by being well cleaned and plunged in solution of sulphate of copper, whereby a thin film of this metal is left upon the iron.

Copper acquires by a certain treatment a reddish or yellowish hue, in consequence of a little oxide being formed upon its surface. Coins and medals may be handsomely bronzed as follows: 2 parts of verdigris and 1 part of sal ammoniac are to be dissolved in vinegar; the solution is to be boiled, skimmed, and diluted with water till it has only a weak metallic taste, and upon further dilution lets fall no white precipitate. This solution is made to boil briskly, and is poured upon the objects to be bronzed, which are previously made quite clean, particularly free from grease, and set in another copper pan. This pan is to be put upon the fire, that the boiling may be renewed. The pieces under operation must be so laid that the solution has free access to every point of their surface. The copper hereby acquires an agreeable reddish brown hue, without losing its lustre. But if the process be too long continued, the coat of oxide becomes thick, and makes the objects appear scaly and dull. Hence they must be inspected every five minutes, and be taken out of the solution the moment their colour arrives at the desired shade. If the solution be too strong, the bronzing comes off with friction, or the copper gets covered with a white powder, which becomes green by exposure to air, and the labour is consequently lost. The bronzed pieces are to be washed with many repeated waters, and carefully dried, otherwise they would infallibly turn green. To give fresh-made bronze objects an antique appearance, three quarters of an ounce of sal ammoniac, and a drachm and a half of binoxalate of potash (salt of sorrel) are to be dissolved in a quart of vinegar and a soft rag or brush moistened with this solution is to be rubbed over the clean bright metal, till its surface becomes entirely dry by the friction. This process must be repeated several times to produce the full effect; and the object should be kept a litle warm. Copper acquires very readily a brown color by rubbing it with a solution of the common liver of sulphur, or sulphuret of potash.

The Chinese are said to bronze their copper vessels by taking 2 ounces of verdigris, 2 ounces of cinnabar, 5 ounces of sal ammoniac, and 5 ounces of alum, all in powder, making them into a paste with vinegar, and spreading this pretty thick like a pigment on the surfaces previously brightened. The piece is then to be held a little while over a fire, till it becomes uniformly heated. It is next cooled, washed, and dried; after which it is treated in the same way once and again till the wished for color is obtained. An addition of sulphate of copper makes the color incline more to chestnut brown, and of borax more to yellow. It is obvious that the cinnabar produces a thin coat of sulphuret of copper upon the surface of the vessel, and might probably be used with advantage by itself.

To give the appearance of antique bronze to modern articles, we should dissolve 1 part of sal ammoniac, 3 parts of cream of tartar, and 6 parts of common salt in 12 parts of hot water, and mix with the solution 8 parts of a solution of nitrate of copper of specific gravity 1·160. This compound, when applied repeatedly in a moderately damp place to bronze, gives it in a short·time a durable green coat, which becomes by degrees very beautiful. More salt gives it a yellowish tinge, less salt a blueish cast. A large addition of sal ammoniac accelerates the operation of the mordant.

Bronze Powders, an article much used of late in the decorative painting of houses, &c. They are prepared of every various shade, from that of bright gold to orange, dark copper, emerald green, &c. Pale gold is produced from an alloy of 13¼ of copper, and 2¾ of zinc: crimson metallic lustre—from copper: do. paler, copper and a very little zinc: green bronze with a proportion of verdigris: another fine orange by 14½ copper and 1¾ zinc: another do. 13¾ copper and 2¼ zinc: a beautiful pale gold from an alloy of the two metals in atomic proportions. See Atomic Weights.

The alloy is laminated into very fine leaves with careful annealing, and these are levigated into impalpable powders along with a film of fine oil to prevent oxidizement, and to favour the levigation. This Nuremberg manufacture. has been successfully introduced here by Mr. Bessemer.

Browning *of gun-barrels and other arms.*—By this process, the surface of several articles of iron acquires a shining brown color. This preparation, which protects the iron from rust, and also improves its appearance, is chiefly employed for the barrels of fowling-pieces and soldiers' rifles, to conceal the fire-arms from the game and the enemy. The finest kind of browning is the Damascus, in which dark and bright lines run through the brown ground.

This operation consists in producing a very thin uniform film of oxyde or rust upon the iron, and giving a gloss to its surface by rubbing wax over it, or coating it with a shellac varnish.

Several means may be employed to produce this rust speedily and well. The effect may be obtained by enclosing the barrels in a space filled with the vapor of muriatic acid. Moistening their surface with dilute muriatic or nitric acid, will answer the same purpose. But the most common material used for browning, is the butter or chloride of antimony, which, on account of its being subservient to this purpose, has been called *bronzing salt*. It is mixed uniformly with olive oil, and rubbed upon the iron slightly heated; which is afterwards exposed to the air, till the wished-for degree of browning is produced. A little aquafortis is rubbed on after the antimony, to quicken its operation. The brown barrel must be then carefully cleaned, washed with water, dried, and finally polished, either by the steel burnisher, or rubbed with white wax, or varnished with a solution of 2 ounces of shellac, and three drachms of dragon's blood, in 2 quarts of spirit of wine.

The following process may also be recommended: Make a solution with half an ounce of aquafortis, half an ounce of sweet spirit of nitre, 1 ounce of spirit of wine, 2 ounces of sulphate of copper, and 1 ounce of tincture of iron, in so much water as will fill altogether a quart measure. The gun barrel to be browned must first of all be filed and polished bright, and then rubbed with unslaked lime and water to clear away all the grease. Its two ends must now be stopped with wooden rods, which may serve as handles, and the touch-hole must be filled with wax. The barrel is then to be rubbed with that solution, applied to linen rags or a sponge, till the whole surface be equally moistened; it is allowed to stand 24 hours, and is then scrubbed with a stiff brush. The application of the liquid and the brushing may be repeated twice or oftener till the iron acquires a fine brown colour. After the last brushing, the barrel must be washed with plenty of boiling water, containing a little potash; then washed with clean water, dried, rubbed with polishing hard wood, and coated with shell-lac varnish, for which purpose the barrel must be heated to the boiling point of water. It is finally polished with a piece of hard wood.

Storch recommends to make a browning solution with 1 part of sulphate of copper, one third of a part of sulphuric ether, and 4 parts of distilled water.

To give the damask appearance, the barrel must be rubbed over first with very dilute aquafortis and vinegar, mixed with a solution of blue vitriol; washed and dried, and rubbed with a hard brush to remove any scales of copper which may be precipitated upon it from the sulphate.

Statues, vases, bas-reliefs, and other objects made of gypsum, may be durably bronzed, and bear exposure to the weather better than after the ordinary oil-varnish, by the following process:—Prepare a soap from linseed oil, boiled with caustic soda ley, to which add a solution of common salt, and concentrate it by boiling, till it becomes somewhat granular upon the surface. It is then thrown upon a piece of linen cloth, and strained with moderate pressure. What passes through is to be diluted with boiling water, and again filtered. On the other hand, 4 parts of blue vitriol and 1 part of copperas are to be dissolved separately in hot water. This solution is to be poured slowly into the solution of soap, as long as it occasions any precipitate. This flocculent matter is a mixture of cupreous soap and ferruginous soap, that is, a combination of the oxides of copper and iron with the margaric acid of the soda soap. The copper soap is green, the iron soap is reddish brown, and both together resemble that green rust which is characteristic of the antique bronzes. When the precipitate is completely separated, a fresh portion of the vitriol solution is to be poured upon it in a copper pan, and is made to boil, in order to wash it. After some time, the liquid part must be decanted, and replaced by warm water for the purpose of washing the metallic soaps. They are finally treated with cold water, pressed in a linen bag, drained and dried. In this state the compound is ready for use in the following way:—

Three pounds of pure linseed oil are to be boiled with 12 ounces of finely-powdered litharge, then strained through a coarse canvass cloth, and allowed to stand in a warm place till the soap turns clear. Fifteen ounces of this soap-varnish, mixed with 12 ounces of the above metallic soaps, and 5 ounces of fine white wax, are to be melted together at a gentle heat in a porcelain basin, by means of a water bath. The mixture must be kept for some time in a melted state, to expel any moisture which it may contain. It must be then applied, by means of a painter's brush, to the surface of the gypsum previously heated to the temperature of about 200° F. By skilful management of the heat the colour may be evenly and smoothly laid on without filling up the minute lineaments of the butts. When after remaining in the cool air for a few days, the smell of the pigment has gone off, the surface is to be rubbed with cotton wool, or a fine linen rag, and variegated with a few streaks of metal powder or shell gold. Small objects may be dipped in the melted mixture, and then exposed to the heat of a fire till they are thoroughly penetrated and evenly coated with it.

The *patina antica* (*Ærugo nobilis*) of the Italian antiquaries is said to be imitated by plunging the copper medals in a boiling-hot solution of 2 parts of verdigris and 1 of sal ammoniac, so much diluted as to be nearly tasteless. They are allowed to remain in the solution till they take an agreeable reddish or yellowish brown colour, when the fluid is to be poured off, and the medals washed and dried.

Bronze Powder consists of a metallic alloy reduced to thin laminæ by beating between skins or membranes in the ordinary way, and then triturated into fine powder along with oil, to prevent oxidation by the atmosphere. The leaves are put first into an iron wire sieve of ten meshes to the inch; olive oil is then allowed to flow freely from a stopcock over the centre of the sieve on to the leaf metal, which is briskly moved over the surface of the sieve with a wire brush, until the whole is forced through into a vessel below. This mixture of metal and oil is then introduced through a funnel hopper of the triturating machine, and spreading among the rods is caused by their rotation to approach the periphery of the steel bed beneath, and escape into a circular trough, whence they are conducted by a spout into another vessel. In this progress the metal is acted upon by polished hemispherical bottom ends of upright rods, as they ascend and descend the corrugated surface of the steel bed, and which, by a tearing and burnishing operation, separate the coarse pieces of leaf into a multitude of polished particles. By being passed three times through the machine, the metal is reduced to the quality of a coarse bronze powder; and is then subjected to a similar machine containing smaller rods, tossed up and down by the revolution of the corrugated angular bed on which they rapidly dance till the requisite fineness be produced. The contents of the vessel, which are usually 10 pounds of metal and 10 pounds of oil, are then put into a strong bag, made of three thicknesses of fustian, with their respective seams at different parts of the circumference, so as to prevent the metallic particles from passing

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through. This bag is subjected to the action of a hydraulic press, of about 300 tons upon a bag of one foot diameter, nearly all the oil is expelled. The empty bag is filled with boiling water, and again squeezed; and after two or three repetitions of this washing, all the oil comes out in the form of an emulsion. The bag now contains only a dense lump of bright metallic particles of nearly the gravity of the original metal. This lump is cut with a knife into slices about half an inch thick, and exposed to the air of a warm room, where the moisture evaporates, and the slices may then be crumbled into powder. (*Newton's Journal*, xxiv. 321.)

BRONZING (*of Objects in Imitation of Metallic Bronze*). Plaster of Paris, paper, wood, and pasteboard, may be made to resemble pretty closely the appearance of articles of real bronze, modern or antique. The simplest way of giving a brilliant aspect of this kind is with a varnish made of the waste gold leaf of the beater, ground up on a porphyry slab with honey or gum-water. A coat of drying linseed-oil should be first applied, and then the metallic powder is put on with a linen dossil. Mosaic gold ground up with six parts of bone-ashes has been used in the same way. When it is to be put on paper, it should be ground up alone with white of eggs or spirit varnish, applied with a brush, and burnished when dry. When a plate of iron is plunged into a hot solution of sulphate of copper, it throws down fine scales of copper, which being repeatedly washed with water, and ground along with six times its weight of bone-ashes, forms a tolerable bronzing.

Powdered and sifted tin may be mixed with a clear solution of isinglass, applied with a brush, and burnished or not, according as a bright or dead surface is desired. Gypsum casts are commonly bronzed by rubbing brilliant black-lead, *graphite*, upon them with a cloth or brush. Real bronze long exposed to the air gets covered with a thin film of carbonate of copper, called by virtuosi antique *ærugo* (*patine antique*, Fr.). This may be imitated in a certain degree by several applications skilfully made. The new bronze being turned or filed into a bright surface, and rubbed over with dilute aquafortis by a linen rag or brush, will become at first greyish, and afterwards take a greenish blue tint; or we may pass repeatedly over the surface a liquor composed of 1 part of sal ammoniac, 3 parts of carbonate of potash, and 6 of sea-salt dissolved in 12 parts of boiling water, to which 8 parts of nitrate of copper are to be added; the tint thereby produced is at first unequal and crude, but it becomes more uniform and softer by time. A fine *green-blue* bronze may be obtained with very strong water of ammonia alone, rubbing it at intervals several times upon the metal.

The base of most of the secret compositions for giving the antique appearance is vinegar with sal ammoniac. Skilful workmen use a solution of 2 ounces of that salt in an English quart of French vinegar. Another compound which gives good results is made with an ounce of sal ammoniac, and a quarter of an ounce of salt of sorrel (binoxalate of potash) dissolved in vinegar. One eminent Parisian sculptor makes use of a mixture of half an ounce of sal ammoniac, half an ounce of common salt, an ounce of spirits of hartshorn, and an English quart of vinegar. A good result will also be obtained by adding half an ounce of sal ammoniac, instead of the spirits of hartshorn. The piece of metal being well cleaned, is to be rubbed with one of these solutions, and then dried by friction with a fresh brush. If the hue be found too pale at the end of two or three days, the operation may be repeated. It is found to be more advantageous to operate in the sunshine than in the shade.

BROWN DYE. Upon this subject some general views are given in the article Dyeing, explanatory of the nature of this colour, to which I may in the first place refer. This dye presents a vast variety of tints, from yellow and red to black brown, and is produced either by mixtures of red, yellow, and blue with each other, or of yellow or red with black, or by substantive colours, such as catechu or oxide of manganese, alone. We shall here notice only the principal shades; leaving their modifications to the caprice or skill of the dyer.

1. Brown from mixture of other colours.

Wool and woollen cloths must be boiled with one eighth their weight of alum and sulpho-tartrate of iron (see this article); afterwards washed, and winced through the madder bath, which dyes the portion of the stuff imbued with the alum red, and that with the salt of iron black; the tint depending upon the proportion of each, and the duration of the madder bath.

A similar brown is produced by boiling every pound of the stuff with two ounces of alum, and one ounce of common salt, and then dyeing it in a bath of logwood containing either sulphotartrate, acetate, or sulphate of iron. Or the stuff may be boiled with alum and tartar, dyed up in a madder bath, and then run through a black bath of iron mordant and galls or sumach. Here the black tint is added to the red till the proper hue be hit. The brown may be produced also by adding some iron liquor to the madder bath, after the stuff has been dyed up in it with alum and tartar. A better brown of this kind is obtained by boiling every pound of wool with 2 ounces of alum, dyeing it up in cochineal, then changing the crimson thus given into brown, by turning the stuff through the bath after acetate of iron has been added to it. Instead of the cochineal, archil, or cutbear, with a little galls or sumach, may be used.

Wool or silk may also receive a light blue ground from the indigo vat, then be mordanted with alum, washed, and turned through a madder bath till the wished-for brown be brought out. For the deeper shades, galls or sumach may be added to the paler Brazil-wood, with more or less iron mordant. Instead of the indigo vat, Saxon blue may be employed to ground the stuff before dyeing it with madder, or 5 pounds of madder, with 1 pound of alum, a solution of one tenth of a pound of indigo in sulphuric acid, may be used with the proper quantity of water for 20 pounds of wool; for dark shades, some iron mordant may be added. Or we may combine a bath of cochineal or cutbear, fustic, and galls, and add to it sulphate of iron and sulphate of indigo, blunted with a little potash.

If we boil woollen cloth with alum and tartar, then pass it through a madder bath, and afterward through one of weld or fustic, containing more or less iron mordant, we obtain shades variable, according to the proportions of the materials, from *mordoré* and cinnamon to chestnut brown.

After the same manner, bronze colors may be obtained from the union of olive dyes with red. For 25 pounds of cloth, we take 4 pounds of fustic chips, boil them for 2 hours, turn the cloth in this bath for an hour, and drain it; then add to the bath from 4 to 6 ounces of sulphate of iron, and 1 pound of ordinary madder, or 2 pounds of sandal-wood; put the cloth again in this compound bath, and turn it through, till the desired shade be obtained. By changing the proportions, and adding an iron mordant, other tints may be produced.

This mode of dyeing is suitable for silk, but with three different baths; one, of logwood, one of Brazil-wood, and one of fustic. The silk, after being boiled with soap, is to be alumed, and then dyed up in a bath compounded of these three decoctions, mixed in the requisite proportions. By the addition of walnut peels, sulphate of copper, and a little sulphate of iron, or by passing the silk through a bath of annotto, a variety of brown shades may be had.

Or the silk may receive an annotto ground, and then be passed through a bath of logwood or Brazil-wood. For 10 pounds of silk, 6 ounces of annotto are to be taken, and dissolved with 18 ounces of potashes in boiling water. The silk must be winced through this solution for 2 hours, then wrung out, dried, next alumed, passed through a bath of Brazil-wood, and finally through a bath of logwood, containing some sulphate of iron It is to be wrung out and dried.

Brown of different shades is imparted to cotton and linen, by impregnating them with a mixed mordant of acetates of alumina and iron, and then dyeing them up, either with madder alone, or with madder and fustic. When the aluminous mordant predominates, the madder gives an amaranth tint. For horse-chestnut brown, the cotton must be galled, plunged into a black bath, then into a bath of sulphate of copper, next dyed up in a decoction of fustic, wrung out, passed through a strong madder bath, then through the sulphate of copper solution, and finished with a soap boil. Different shades of cinnamon are obtained, when cottons first dyed up with madder get an olive cast with iron liquor in a fustic bath.

These cinnamon and mordoré shades are also produced by dyeing them first in a bath of weld and verdigris, passing them through a solution of sulphate of iron, wringing and drying them; next putting them through a bath containing 1 pound of galls for 10 pounds of stuff, again drying, next aluming, and maddering. They must be brightened by a boil in soap water.

A superior brown is produced by like means upon cotton goods, which have undergone the oiling process of the Turkey red dye. Such stuffs must be galled, mordanted with alum (see MADDER), sulphate of iron, and acetate of lead (equal to ⅔ of the alum); after washing and drying, dyed in a madder bath, and cleared with a soap boil. The tint of brown varies with the proportion of alum and sulphate of iron.

We perceive from these examples, in how many ways the browning of dyes may be modified, upon what principles they are founded, and how we have it in cur power to turn the shade more or less toward red, black, yellow, blue, &c.

Brown may be produced by direct dyes. The decoction of oak bark dyes wool a fast brown of different shades, according to the concentration of the bath. The color is more lively with the addition of alum.

The decoction of bastard marjoram (*Origanum vulgare*) dyes cotton and linen a reddish brown, with acetate of alumina. Wool takes from it a dark brown.

The bark of the mangrove tree (*Rizophora mangle*) affords to wool boiled with alum and tartar a fine red brown colour, which, with the addition of sulphate of iron, passes into a fast chocolate.

The *Bablah*, the pods of the East Indian *Mimosa cineraria*, and the African *Mimosa nilotica*, gives cotton a brown with acetate or sulphate of copper.

The root of the white sea rose (*Nymphæa alba*) gives to cotton and wool beautiful

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shades of brown. A mordant of sulphate of iron and zinc is first given, and then the wool is turned through the decoction of the root, till the wished-for shade is obtained. The cotton must be mordanted with a mixture of the acetates of iron and zinc.

Walnut peels (*Juglans regia*), when ripe, contain a dark brown dye stuff, which communicates a permanent color to wool. The older the infusion or decoction of the peels, the better dye does it make. The stuff is dyed in the lukewarm bath, and needs no mordant, though it becomes brighter with alum. Or this dye may be combined with the madder or fustic bath, to give varieties of shade. For dyeing silk, this bath should be hardly lukewarm, for fear of causing inequality of color.

The peelings of horse-chestnuts may be used for the same purpose. With muriate of tin they give a bronze color, and with acetate of lead a reddish brown.

Catechu gives cotton a permanent brown dye, as also a bronze, and mordoré, when its solution in hot water is combined with acetate or sulphate of copper, or when the stuff is previously mordanted with the acetates of copper and alumina mixed, sometimes with a little iron liquor, rinsed, dried, and dyed up, the bath being at a boiling heat.

Ferrocyanate of copper gives a yellow brown or a bronze to cotton and silk.

The brown color called *carmelite* by the French is produced by one pound of catechu to four ounces of verdigris, with five ounces of muriate of ammonia. The bronze (*solitaire*) is given by passing the stuff through a solution of muriate or sulphate of manganese, with a little tartaric acid, drying, passing through a potash ley at 4° Baumé, brightening and fixing with solution of chloride of lime.

BRUSHES. (*Brosses*, Fr.; *Bürsten*, Germ.) Mr. T. Mason obtained a patent in October, 1830, for an improvement in the manufacture of this article. It consists in a firmer mode of fixing the knots or small bundles of hair into the stock or the handle of the brush. This is done by forming grooves in the stocks of the brushes, for the purpose of receiving the ends of the knots of hair, instead of the holes drilled into the wood, as in brushes of the common constructions. These grooves are to be formed like a dovetail, or wider at the bottom than the top; and when the ends of the knots of hair have been dipped into cement, they are to be placed in the grooves and compressed into an oval form, by which the ends of the hair will be pressed outwards into the recess or wider part of the dovetailed groove, or the grooves may be formed with threads or teeth on the sides, instead of being dovetailed; and the cement and hairs being pressed into the teeth or threads, will cause them to adhere firmly to the stock or handle of the brush.

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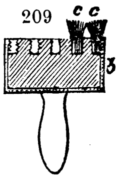

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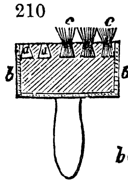

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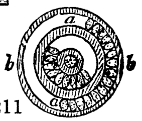

A metal ferrule may be placed on the outside of the stock of the brush, if necessary, and secured by pins or rivets, or in any other convenient manner, which ferrule may also form one side of the outer groove. *Fig.* 209 is a plan view of the stock of a round brush; *fig.* 210 is a section of the same; *a a* are the dovetailed grooves, which are turned out of the wood; *b* is the metal ferrule; *c c* are knots or small bundles of hair, to form the brush. After a number of the knots of hair are prepared, the ends are to be dipped into proper cement, and then placed into the grooves, when their ends are to be squeezed by a pair of pliers, or other means, which will compress them into the oval shape, as shown in *fig.* 211 and cause the ends of the hairs to extend outward under the dovetailed part of the recess.

The knots of hair are to be successively placed in the grooves, and forced up by a tool against the last knot put in, and so on, until the grooves are filled; *fig.* 211 is a section taken through a brush with teeth or threads of a screw formed upon the sides of the groove; into these teeth or threads the cement and hairs will be forced by the compression, by which means they will be held firmly in the stock of the brush.

BUTTER. (*Beurre*, Fr.; *Butter*, Germ.) Milk contains a fatty matter of more or less consistency, modified very much according to the nature of the animals which afford it. This substance is butter, held suspended in the milk by means of the caseous matter and whey, with which it is intimately blended. Milk is a true emulsion resulting from the mixture of these three ingredients, owing its opacity and white color to the diffusion through it of that butyraceous oil. When any circumstance dissolves this union, each component becomes insulated, and manifests its peculiar properties. Milk, even left to itself, at a temperature of from 50° to 60° F., separates spontaneously into several products. A layer of a fatter, more consistent, but lighter nature floats on its surface, while the subjacent liquid forms a white magma, which retains among its curdy flocks all the whey of the milk. The upper layer or cream contains nearly the whole of the butter; but a portion remains entangled with the curd and whey below.

It belongs to a work on husbandry or rural economy to treat fully of the operations of the dairy: one of the principal of which is the extraction of butter from milk.

The Tartars and French have been long in the habit of preserving butter, by melting it with a moderate heat, whereby are coagulated the albuminous and curdy matters remaining in it, which are very putrescible. This fusion should be made by a heat of a water bath, about 176° F., continued for some time to effect the more complete purification of the butter. If in this settled liquefied state it be carefully decanted, strained through a tammy cloth, and slightly salted, it may be kept for a long time nearly fresh, without becoming in any degree rancid, more especially if it be put up in small jars closely covered.

Butter is the fatty matter of milk, usually of that of the cow. Milk is composed of butter, caseine, sugar of milk, several salts, and water. The butter exists in the form of very small globules of nearly uniform size, quite transparent, and strongly refractive of light. Milk left in repose throws up the lighter particles of butter to the surface as cream. It was imagined that the butter was separated in the process of churning, in consequence of the milk becoming sour; but this is not the case, for milk rendered alkaline by bicarbonate of potash affords its butter fully more readily than acidulous milk. The best temperature for churning milk or cream is 53° F.; that of 60° is too high; and under 50° it is too low. By the churning action the heat rises from 3 to 4 degrees F. All the particles of butter are never separated by churning; many remain diffused through the butter-milk, and are easily discoverable by the microscope. These are more numerous in proportion to the bulk of the liquid; and hence it is more economical to churn cream than the whole milk which affords it. It is computed that a cow which gives 1800 quarts (old English) of milk per annum eats in that time 8000 lbs. of hay, and produces 140 lbs. of butter.* Analysis shows that this weight of hay contains 168 pounds of fat. The finest flavoured butter is obtained from milk churned not long after it is drawn; but the largest proportion is derived from the cream thrown up by milk after standing 24 hours, in a temperature of about 50° F. The butter-milk, which contains the very fermentable substance, caseine, should be well separated from the butter by washing with cold water, and by beating with the hands, or preferably, without water, for the sake of fine flavour, by the action of a press.

The French purify their butter by melting it in pots, plunged into water heated to 200° or 212°; and sometimes they mix a pure brine with the melting butter, whereby they favour the subsidence of the coagulated caseine and other impurities. The supernatant clear butter should be drawn or poured off, and rapidly cooled, to prevent the crystallization of its stearine and separation of its oleine, which injure its flavour and appearance.

Butter of Cacao. See Cacao, Chocolate, and Oils.

BUTTON MANUFACTURE. This art is divided into several branches, constituting so many distinct trades. Horn, leather, bone, and wood, are the substances frequently employed for buttons, which are either plain, or covered with silk, mohair, thread, or other ornamental materials. The most durable and ornamental buttons are made of various metals, polished, or covered with an exceedingly thin wash, as it is termed, some more valuable metal, chiefly tin, silver, and gold.

Those buttons intended to be covered with silk, &c., are termed in general moulds. They are small circles, perforated in the centre, and made from those refuse chips of bone which are too small for other purposes. These chips, which for the large and coarser buttons, are pieces of hard wood, are sawn into thin flakes, of an equal thickness; from which, by a machine, the button moulds are cut out at two operations.

The shavings, sawdust and more minute fragments are used by manufacturers of cutlery and iron toys, in the operations of case-hardening; so that not the smallest waste takes place.

Metal buttons are formed of an inferior kind of brass, pewter, and other metallic compositions: the shanks are made of brass or iron-wire, the formation of which is a distinct trade. The buttons are made by casting them round the shank. For this purpose the workman has a pattern of metal, consisting of a great number of circular buttons, connected together in one plane by very small bars from one to the next; and the pattern contains from four to twelve dozen of buttons of the same size. An impression from this pattern is taken in sand in the usual manner; and shanks are pressed into the sand in the centre of each impression, the part which is to enter the metal being left projecting above the surface of the sand. The buttons are now cast from a mixture of brass and tin; sometimes a small proportion of zinc is added, which is found useful in causing the metal to flow freely into the mould, and makes a sharp casting. When the buttons are cast, they are cleaned from the sand by brushing; they are then broken asunder, and carried to a second workman at the lathe, who inserts the shank of a button into a chuck of a proper figure, in which it is retained by

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* Two pounds and a quarter of hay correspond to one quart of good milk; and a cow which eats 6,500 lbs. of hay will produce 300 lbs. of butter per annum.

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the back centre of the lathe being pressed against the button with a spring. The circumference is now, by filing it as it turns around, reduced to a true circle; and the button is instantly released by the workman's holding back the centre, and is replaced by another. A third workman now turns the back of the button smooth, in a chuck lathe, and makes the projecting part round the shank true; and a fourth renders the face of the button smooth, by placing it in a chuck, and applying the edge of a square bar of steel across its centre.

Gilt buttons are stamped out from copper (having sometimes a small alloy of zinc), laminated in the flatting mill to the proper thickness. The stamp is urged by a fly-press, which cuts them out at one stroke. These circular pieces, called blanks, are annealed in a furnace to soften them; and the maker's name, &c. is struck on the back by a monkey, which is a machine very similar to a pile engine. This stamp also renders the face very slightly convex, that the buttons may not stick together in the gilding process. The shanks are next soldered on. The burnishing is performed by a piece of hematites or blood-stone, fixed into a handle, and applied to the button as it revolves by the motion of the lathe.

A great number of the buttons, thus prepared for gilding, are put into an earthen pan, with the proper quantity of gold to cover them,* amalgamated with mercury in the following manner:—The gold is put into an iron ladle, and a small quantity of mercury added to it; the ladle is held over the fire, till the gold and mercury are perfectly united. This amalgam being put into the pan with the buttons, as much aquafortis, diluted with water, as will wet them all over, is thrown in, and they are stirred up with a brush, till the acid, by its affinity to the copper, carries the amalgam to every part of its surface, covering it with the appearance of silver. When this is perfected, the acid is washed away with clean water. This process by the workman is called quicking.

The old process in gilding buttons, called the drying off, was exceedingly pernicious to the operator, as he inhaled the vapour of the mercury, which is well known to be a violent poison. In order to obviate this, the following plan of apparatus has been employed with success. The vapour, as it rises from the pan of buttons heated by a charcoal fire, is conducted into an oblong iron flue or gallery, gently sloped downwards, having at its end a small vertical tube dipping into a water cistern, for condensing the mercury, and a large vertical pipe for promoting the draught of the products of the combustion.

Plated buttons are stamped by the fly-press, out of copper-plate, covered on one side with silver at the flatting mill. The copper side is placed upwards in stamping, and the die or hole through which they are stamped, is rather chamfered at its edge, to make the silver turn over the edge of the button. The backs are stamped in the same manner as the gilt buttons. The shanks are soldered on with silver solder, and heated one by one in the flame of a lamp, with a blow-pipe urged by bellows. The edges are now filed smooth in the lathe, care being taken not to remove any of the silver which is turned over the edge. They are next dipped in acid, to clean the backs, and boiled in cream of tartar and silver, to whiten them; after which they are burnished, the backs being first brushed clean by a brush held against them as they revolve in the lathe. The mode of burnishing is the same as for gilt buttons.

Button shanks are made by hand from brass or iron wire, bent and cut by the following means:—

The wire is lapped spirally round a piece of steel bar. The steel is turned round by screwing it into the end of the spindle of a lathe, and the wire by this means lapped close round it till it is covered. The coil of wire thus formed is slipped off, and a wire fork or staple with parallel legs put into it. It is now laid upon an anvil, and by a punch the coil of wire is struck down between the two prongs of the fork, so as to form a figure 8, a little open in the middle. The punch has an edge which marks the middle of the 8, and the coil being cut open by a pair of shears along this mark, divides each turn of the coil into two perfect button shanks or eyes.

Mr. Holmes, of Birmingham, obtained in May, 1833, a patent for an improved construction of buttons. *Fig.* 212. represents the outside appearance of one of his improved shanks, as raised or formed out of the disc of metal which is to constitute the back of the button; *fig.* 213, an edge view, looking through the shank or loop; *fig.* 214. is another edge view, looking at the raised shank or loop endways; *fig.* 215. is a section taken through the shank and disc in the direction of the dotted line A B, in *fig.* 212.; and *fig.* 216. another section taken in the direction of the dotted line C D, in *fig.* 212. All these figures of his improved shanks, as well as those hereinafter described, together with the tools used to form the same, are drawn at about half the real size, to show the parts more distinctly. It will be seen that the shanks or loops *a a* are formed by partially cutting and raising, or forcing up a portion of the metal disc or back *b*, and are compressed or formed by the action of the tools, or punches and dies, so as to have a rounded figure on the inside of the top part of the shank, as at *c*, the edges of the metal being turned so as to prevent them cutting the threads by which the button is fastened to the cloth or garment. It will be observed that, there being but one passage or way through which the thread can be passed to sew on the button, and that opening being rounded on all edges, will cause the threads to keep in the centre of the shanks, the form of the shank allowing a much neater attachment to the garment, and keeping the threads from the edges of the metal. The ends of the shank or portions *e e*, which rise up from the disc or back *b*, are made nearly circular, in order to avoid presenting any edges of the metal to the sides of the button-hole; and when the shank is sewed on the cloth, it forms, in conjunction with the threads, a round attachment, thereby preventing the shank from cutting or wearing the button-hole: the threads, when the shank is properly sewed to the garment, nearly filling up the opening through the shank, and completing that portion of the circle which has been taken out of the shank by the dies in forming the crescented parts of the loop. It will be therefore understood that the intention is, that the inside edges of the shank should be turned as much as possible away from the threads by which the button is sewed on the cloth, and that the outside of the shank should be formed so as to present rounded surfaces to the button-hole, and that the thread should fill up the opening through the shank, so as to produce a round attachment to the garment. It should here be observed, that the backs of the buttons shown in these figures are of the shape generally used for buttons covered with Florentine or other fabric, or faced with plates of thin metal, and are intended to have the edges of a disc, or what is termed a shell, forming the face, to be closed in upon the inclined or bevelled edges of the backs. Having now described the peculiar form of the improved shanks which he prefers, for buttons to be covered with Florentine or other fabric, or shells of thin metal plate, he proceeds to describe some of the different variations from the same.

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* By act of parliament 5 grains of gold are allotted for the purpose of gilding 144 buttons, though they may be tolerably well gilt by half that quantity. In this last case, the thickness would be about the 214,000th part of an inch.

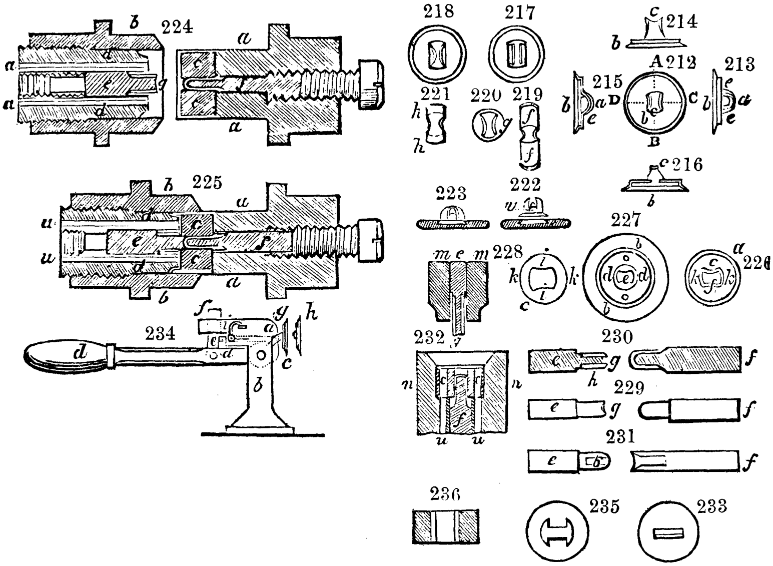

Fig. 217. is a representation of a shank, the cut through the disc or back being effected by a parallel rib on the die, and corresponding groove in the shaping punch, instead of the semi-circular or crescented cut shown in *fig.* 212; *fig.* 218. is a view of another shank, the separation of the sides of the loop being performed by straight edges in both punch and die. He prefers finishing this shaped shank (that is, giving it the rounded form, to prevent its cutting the threads), by detached punches, and dies, or pincers, as will be hereinafter described. *Fig.* 219. is a representation of one of the improved shanks, which has merely portions, *f f*, of the back of the button connected to its ends. This shank may be used for buttons which have a metal shell to be closed in upon the bevelled edges of the ends, or the shank piece may be otherwise connected to the face part of the button. *Fig.* 220. is a representation of a shank raised out of a small disc of metal *g g*, intended to be soldered to the disc of metal forming the button, or it may be otherwise fixed to the back; *fig.* 221. is a representation of another shank for the same purpose, having only portions of metal *h h*, for soldering or otherwise attaching it to the back of the button, as by placing a ring or annular piece over it forming the back, which shall be confined to the face, as before described; *fig.* 222. is a representation of a shank raised upon a dish or bevelled piece of metal, and is intended to be used for buttons made from pearl-shell, horn, wood, paper, or other substances. The back part of the button has a dovetailed recess formed in it to receive the dish-shaped back, which is pressed into the recess, the edges of the dish being expanded in the dovetailed parts of the recess by the ordinary means, and thereby firmly fixing it to the button, as shown in *fig.* 223.

Having now explained the peculiar form of his improved shanks, he proceeds to describe the tools, or punches and dies, by which he cuts the disc or back from out of a sheet of metal, and at the same operation produces and forms the shank complete. *Fig.* 224. is a longitudinal section taken through a pair of dies and punches when separated; *fig.* 225. is a similar section, taken when they are put together, and in the act of forming a shank after cutting out the disc or back of the button from a sheet of metal; *fig.* 226. is a face view of the punch; and *fig.* 227. is a similar representation of the counter die, with the tools complete; *a* is the puncher or cutter, and *b* the counter bed, by the circular edges of which the disc of metal is cut out of the sheet; *c* is a die, fixed in the cutter *a*, (upon which the name of the button maker may be engraved.) *Fig.* 228. is a face view of this die when removed out of the punch; *d* is the counter die to the die *c*. It will be perceived that these dies *c* and *d*, together with the punch and bed, compress the disc of metal into the form required for the back of the button; that shown in the figures, as before stated, is of the shape used for buttons to be covered with Florentine or thin plate metal, in a round shell closed in upon the inclined or bevelled edge of the back; *e* is the cutting and shaping punch of the shank, which is fixed within the counter die; this punch cuts through the metal of the disc, and forms the shank as the dies approach nearer together, by raising or forcing it up into the recess or opening in the die *c*, where it is met by the end of another shaping punch *f*, fixed in the punch *a*, which compresses the upper part of the shank into the recess *g*, in the end of the punch *e*, thereby giving the shank its rounded figure, and at the same time forming the other part of the shank into the required shape, as described at *figs.* 212. to 216. The ends of these shaping punches fit into and over each other, as will be seen by the detached figures of the punches designed for forming the shank first described. *Fig.* 229. is a representation of the punches when apart and removed out of the dies: *fig.* 230. is a longitudinal section of the same; *fig.* 231. is another view of the punches as seen on the top. The sharp edge of the recess *h*, in the punch *e*, comes in contact with the cutting edges of the projecting rib *i*, of the die *c*, and thereby cuts through so much of the metal as is required. The edge *k* of this die keeps the outside ends of the shank of a spherical figure, as before explained, while the punches force up the metal, and form the elevated loop or shank: *u u* are holes made through the counter die *d*, for the passage of clearing pins, which force out the shank or back piece from the counter die when finished; the operation of which will be shown when describing the machinery hereafter. There are adjusting screws at the back of the punches and dies, by which they can be regulated and brought to their proper position one to the other.

Although he has shown the punches which form his improved shanks, fixed into and working in conjunction with the punch and dies which cut out and shape the discs of metal for the back of the button, yet he does not intend to confine himself to that mode of using them, as flat blanks or discs for the backs of buttons may be cut out in a separate stamping press, and afterwards shaped in the same press or in another, and then brought under the operation of the punches which form his improved shanks, fixed in any suitable press. This last-mentioned mode of producing button shanks and backs he prefers when such metals are employed as require annealing between the operations of shaping the backs and forming the shank. *Fig.* 232. is a section taken through a pair of dies, in which the operation only of forming the shank is to be performed, the backs being previously shaped in another press. In this instance the punches *e* and *f* are mounted in guide-pieces *m* and *n*, which keep them in the proper position towards each other, the die *c* being mounted in the piece *n*, and acting against the face of the guide *m*. The blanks or backs of the buttons may be fed into these dies by hand or any other means; and after the shank is formed, the finished back can be pushed out of the lower die by clearing rods passed through the holes *u u*, and removed by hand, or in any convenient manner.

When his improved shanks are formed out of iron or other metal which is too brittle to allow of the shank being forced up and finished at one operation in the dies and punches, he prefers cutting out and shaping the blank or back of the button first, and after annealing it, to raise or force up the portion of metal to form the shank into the shape shown in *fig.* 233., that is, without the edges of the metal being turned to prevent their cutting the threads, and after again annealing it, to bend or turn the edges into the shape shown in *fig.* 218. by means of suitable punches in another press, or by a pair of pincers and punch as shown in *fig.* 234, which is a side view of a small apparatus to be used for turning the edges of the shank by hand, with a partly formed shank seen under operation. *a*, is the upper jaw of a pair of pincers, this jaw being fixed on to the head of the standard *b;* the under jaw *c*, is formed by the end of the lever or handle *d*, which has its fulcrum in the standard *b*. *e*, is a small punch, passed through a guide hole in the head of the standard, one end projecting into the jaws of the pincers, the other against a piece *f*, attached by a joint to the lever *d*, and working through a slot in the head of the standard; this piece *f*, has an inclined plane on the side next the end of the punch, which, in its descent, projects the punch forward against the top of the loop of the shank, (placed at *g*,) as the pincers are closed by forcing down the lever *d*, and, in conjunction with the jaws of the pincers, compresses the shank into the required form, as shown at *h*, and in the enlarged *fig*. 218. A spring, *i*, acts against a pin fixed into the punch *e*, for the purpose of bringing it back as the jaws open after forming a shank. *Figs*. 235. and 236. represent the face and section of the dies mentioned before, for cutting the slits in the discs, as at *fig*. 217.

Having explained the peculiar forms of his improved metallic shanks for buttons, and the tools employed in making the same, he proceeds to describe the machinery or apparatus by which he intends to carry his invention into effect. He proposes to take a sheet of metal, say about 30 or 40 feet long, and of the proper width and thickness, which thin sheet is to be wound upon a roller, and placed above the machine, so that it can be easily drawn down into the machine as required for feeding the punches and dies. *Fig*. 237. is a plan view of a machine, intended to work any convenient number of sets of punches and dies placed in rows. Eleven sets of punches and dies are represented, each set being constructed as described under *figs*. 224. to 231.; *fig*. 238. is a side view, and *fig*. 239. a longitudinal section, taken through the machine; *figs*. 240. and 241. are transverse sections taken through the machine between the punches and counter dies, *fig*. 240. representing its appearance at the face of the punches, and *fig*. 241. the opposite view of the counter dies. *a a*, are the punches; *b b*, the counter dies; each being mounted in rows in the steel plates *c c*, fixed upon two strong bars *d* and *e*, by countersunk screws and nuts, the punches and dies being retained in their proper position by the plates, which are screwed on to the front of the steel plates, and press against the collars of the punches and dies. The bars *d* and *e* are both mounted on the guide-pins *g g*, fixed in the heads *h h* of the frame, which guide-pins pass through the bosses on the ends of the bars. The bar *d* is stationary upon the guide-pins, being fixed to the heads *h h*, by nuts and screws passed through ears cast on their bosses. The bar *e* slides freely upon the guide-pins *g g*, as it is

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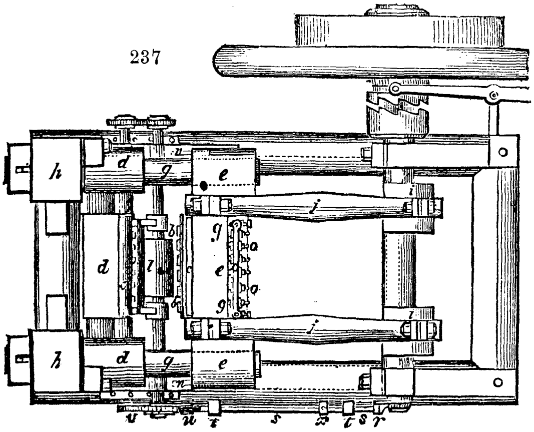

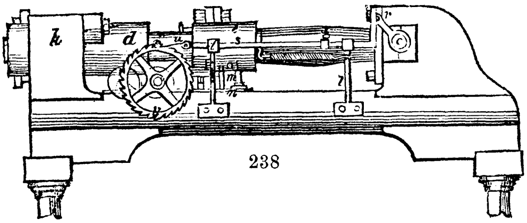

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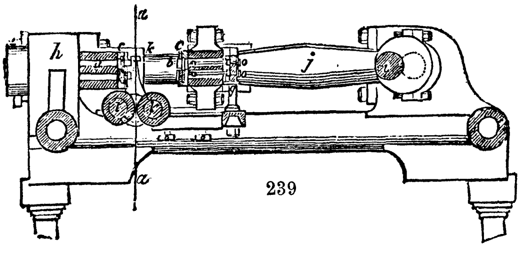

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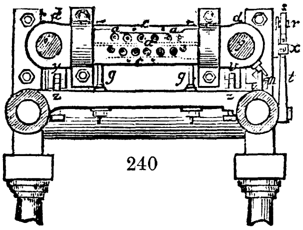
moved backwards and forwards by the crank *i i*, and connecting-rods *j j*, as the crank shaft revolves. The sheet of thin iron to be operated upon is placed, as before stated, above the machine; its end being brought down as at *a a*, and passed between the guide-rod and clearing plate *k*, and between the pair of feeding-rollers *l l*, which, by revolving, draw down a further portion of the sheet of metal between the punches and dies, after each operation of the punches.



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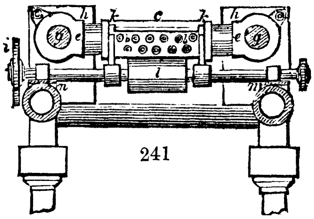

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As the counter dies advance towards the punches, they first come in contact with the sheet of metal to be operated upon; and after having produced the pressure which cuts out the discs, the perforations of the sheet are pushed on to the ends of the punches by the counter dies; and in order that the sheet may be allowed to advance, the carriage which supports the axles of the feeding-rollers, with the guide-rod and clearing-plate, are made to slide by means of the pin *m*, which works in a slot in the sliding-piece *n*, bearing the axis of the feeding-roller *l l*, the slide *n* being kept in its place on the framework by dovetailed guides, shown in *fig.* 241.

When the counter dies have advanced near to the sheet of metal, the pin *m*, comes in contact with that end of the slot in the piece *n*, which is next to the punches, and forces the carriage with feed-rollers and clearing plate, and also the sheet of metal, onwards, as the dies are advanced by the reaction of the cranks; and after they have cut out the discs, and raised the shanks, the sheet of metal will remain upon the punches; and when the bar *e* returns, the finished backs and shanks are forced out of the counter dies, by the clearing-pins and rods *o o*, which project through the bar *e*, and through the holes before mentioned in the counter dies; these clearing-pins being stationary between the bars *p p*, mounted upon the standard *q q*, on the cross bar of the frame, as shown in *figs.* 237. 239. 240. Immediately after this is done, the pins *m* come in contact with the other ends of the slots in the pieces *n*, and draw back the feeding-rollers *l l*, together with the clearing-plate *k*, and the sheet of metal, away from the punches into the position represented in the figures.

At this time the feeding of the metal into the machine is effected by a crank-pin *r*, on the end of the crank-shafts coming in contact with the bent end of the sliding-bar *s*, supported in standards *t t;* and as the crank-shaft revolves, this pin *r* forces the bar *s* forward, and causes the tooth or pall *u*, on its reverse end, to drive the racket-wheel *v*, one or more teeth; and as the racket-wheel *v* is fixed on to the end of the axle of one of the rollers *l*, it will cause that roller to revolve; and by means of the pair of spur-pinions on the other ends of the axles of the feeding-rollers, they will both revolve simultaneously, and thereby draw down the sheet of metal into the machine. It will be perceived that the standards which support the clearing-plate and guide-bar are carried by the axles of the feeding-rollers, and partake of their sliding motion: also that the clearing-pins *o*, are made adjustable between the bars *p*, to correspond with the counter dies. There is an adjustable sliding-stop *x* upon the bar *s*, which comes in contact with the back standard *t*, and prevents the bar *s* sliding back too far, and consequently regulates the quantity of sheet metal to be fed into the machine by the pall and ratchet-wheel, in order to suit different sizes of punches and dies. In case the weight of the bar *c*, carrying the counter dies, should wear upon its bearings, the guide-pins *g g*, have small friction-rollers *y y*, shown under the bosses of this bar, which friction-rollers run upon adjustable beds or planes *z z*, by which means the guide-pins may be partially relieved from the weight of the bar *c*, and the friction consequently diminished.

Buttons of Horn.—Mr. Thomas Harris obtained in April, 1841, a patent for improvements in the manufacture of horn buttons, and in their dies. His invention relates, first, to a mode of applying flexible shanks to horn buttons; secondly, to a mode of ornamenting horn buttons, by inlaying the front surface thereof; thirdly, to a mode of ornamenting what are called horn buttons, by gilding or silvering their surfaces; fourthly, to a mode of constructing dies, by applying separate boundary circles to each engraved surface of a die, by which the process of engraving, as well as the forming of accurate dies, will be facilitated; fifthly, to a mode of constructing dies, used in the manufacture of horn buttons, whereby the horn or hoof employed will not be permitted to be expressed beyond the circumference of the button.

Fig. 242. represents, in section, a pair of dies, A and B, used in producing the improved horn buttons, according to the first improvement; the upper die A is made to produce the back surfaces of the buttons, and the recess or groove for receiving the flexible shank. *Fig.* 243. shows, in section and back view, the form of a button produced by the dies.

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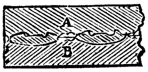

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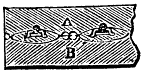

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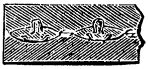

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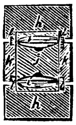

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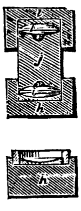

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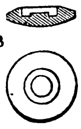

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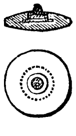

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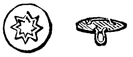

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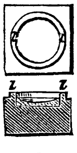

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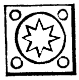

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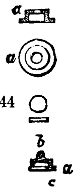

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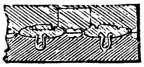

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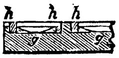

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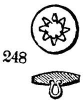

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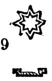

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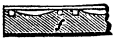

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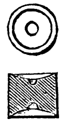

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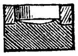

Buttons thus formed are now ready to receive flexible shanks; and if the buttons are to have plain smooth front surfaces, then, in fixing the flexible shanks, the same kind of under die B may be used; but if the front surface of the button is to be embossed or ornamented, then, in place of that die a similar one having engraved or suitably ornamented surfaces, is to be used. When fixing the shanks to buttons, the lower or face die, containing the previously formed buttons, is to be heated till a drop of water will nearly boil upon it.

The shank is applied as follows:—a metal shell or collet *a* (see *fig.* 244.) is placed over the flexible shank *b*, and a plate of metal *c* is laid under the shank; these are placed in the groove or recess of the button, which had been previously heated in the lower die; the upper die A, *fig.* 245., is then to be placed on the lower die B, and the two submitted to pressure, until they become cool, when the shank will be firmly attached, as shown at *fig.* 246., and the bottom may be finished in the usual way.

The second part of the invention, which relates to a mode of ornamenting horn buttons, by inlaying the front surface thereof,is performed in a manner similar to what has been above described, for fixing flexible shanks, and consists in first forming the front face or surface of a button, in suitable dies, for providing a recess; and then, by a second pressure in dies, to fix the ornamental surface; and, when desired, the surrounding front surface of the button may be embossed. *Fig.* 247. is a longitudinal section of a pair of dies, for forming a recess in the face of a button. *Fig.* 248. shows, in front view and section, a horn button, produced by these dies. *Fig.* 249. shows a metal ornament, to be inlaid or fixed in the front surface of the button, but it should be stated that the ornamenting surface, to be fixed in the front surface of the button may be of pearl or other material; and the size and device varied according to taste. *Fig.* 250. shows in section a pair of dies, for giving the second pressure for affixing the ornamental surface; and, if desired, the remaining front surface of the button may be ornamented, by having the lower die engraved, or otherwise suitably ornamented. *Fig.* 251. shows in front view and section a button made according to this part of the invention.

The third part of the invention relates to a mode of ornamenting horn buttons, by gilding or silvering their surfaces. This is effected by applying a suitable cementing or adhesive material with a soft brush to the button, in order that gold or silver leaf may be attached to its surface. The cementing or adhesive material preferred to be used is dressing varnish rendered sufficiently liquid by essence of turpentine; and when the varnish is nearly dry, gold or silver leaf is applied thereto, and pressed in the same manner as practised when gilding and silvering other surfaces; by thus treating horn buttons, a very novel manufacture of that description of buttons may be produced.

The fourth part of this invention relates to the construction of dies used in the manufacture of horn buttons. *Fig.* 252. is a section of a die, constructed according to this part of the invention and *fig.* 253. is a section showing the die without the bounding circles, which confine the pattern; *f* is the die engraved at the parts *g*, *g*; around each of which engraved surfaces are circular grooves or recesses to receive the bounding circles, *h*, *h*, which fit accurately. By the after insertion of these circles, the workman is not confined to move his graver within the bounding line, as that line is not present when engraving the plate; and the graver may pass beyond, and the grooves and the bounding circles may readily be made with great accuracy to each of the engraved surfaces.

The fifth part of the invention also relates to a mode of constructing dies, for the manufacture of horn buttons, and consists in forming the dies, so that the bounding circle shall be of a sufficient depth for the counter die to slide within it, and fit accurately in order that the circumference of each button shall be smoothly and accurately formed. *Fig.* 254. represents in section two dies, and one counter die, made according to this part of the invention; *fig.* 255. shows one of the dies, in plan and section; and *fig.* 256. a plan and section of a counter die, suitable for flexible shank buttons. *h*, *h*, are the dies, having the engraved surfaces *i*, *i*, on separate circular discs of metal, such as have heretofore been used; *j*, is a counter die, and *k*, a tube, within which the counter die is held, the object of this tube being to guide the projecting edges *l*, *l*, of the dies as shown, and thus keep the dies and counter dies correct to each other. *Fig* 257. is a section of two dies *h*, and a counter die *j*; but in this case the tube *k* is dispensed with, the dies being deeper sunk, and thus guiding the counter die correctly. By the use of these dies, the edges of horn buttons will be more accurately formed, and consequently require less finishing. This description of dies may be made according to the mode described in the fourth part of this invention; that is, by forming the boundary circle separately, as will be understood by referring to *fig.* 258., which is a side section of a die complete, with its boundary circle formed in a similar manner to that described above. *Fig.* 259. represents, in plan and section, a variation in the means of affixing a separate bounding circle to each engraved surface; and it is suitable for working without the tube. In using these dies they are to be heated but slightly, whether for buttons with metal shanks, or to receive flexible shanks, and are to be pressed as heretofore. The patentee claims, firstly, the mode of manufacturing horn buttons with flexible shanks, by first forming buttons by pressure and heat, and then by a second pressure in dies, to affix flexible shanks thereto, as above described. Secondly, the mode of ornamenting horn buttons, by causing suitable surfaces to be affixed in the front surfaces, by pressing the buttons with the ornaments in dies, as above described. Thirdly, the mode of ornamenting horn buttons by gilding and silvering their surfaces as described. Fourthly, the mode of constructing dies used in the manufacture of horn buttons, by applying separate bounding circles to each engraved surface for a button; and fifthly, the mode of manufacturing horn buttons in dies, wherein the horn or hoof is prevented from being expressed at the circumference of the buttons as described.

Buttons, Covered. Mr. Joseph Parkes obtained, in 1840, a patent for improvements in the manufacture of covered buttons made by dies and pressure, by the application of horn as a covering material. The process resorted to by the patentees for carrying out this invention, is very similar to that pursued in manufacturing Florentine buttons; such modifications being applied as are rendered necessary for adapting such process to the peculiar nature of the material employed for covering the face of each button. *a*, *fig.* 260. shows a plan of a disc of iron plate, with four projecting points, which is formed by suitable dies in a fly-press, as is well understood; the points are then turned down, and the disc *a*, is sunk into the shape shown at *fig.* 261., and two such sunk discs are applied to the internal core of the button-board of each button; *b*, *fig.* 262., shows a plan and edge view of a circular dise of button-board, suitable for forming the internal core of a button.

The dies being placed in suitable presses, as is well understood in using similar dies in manufacturing Florentine or other covered buttons, one of the sunk dies *a* is placed in the under die, with the points upwards, having a disc of button-board placed on the points, as shown at *fig.* 263.; the upper die or punch is then caused to descend and press the button board *b* into the shape shown at *fig.* 264.; which, when thus formed, is to have a die *a*, applied on the other side, as shown at *fig.* 265. The disc *a*, to be next fixed to the button-board, is placed in a suitable die, the disc which has already been fixed being upwards; the die or punch is now to be pressed down, which will produce the button-board, with the discs *a a* on either side, into the shape shown at *fig.* 266.; and it will be seen, that one of the discs will, by the shape of the die, be sunk concave, whilst the other disc *a*, on the other side, will be formed convex, or according to the figure of the face of the intended button.

The core of button-board, *fig.* 266., is now ready for being inserted into the fabric which is to become the flexible shank of the button, and which flexible shank is formed by sinking a portion of fabric in suitable dies, as is well understood when making similar shanks for Florentine or other covered buttons; and the shank being so sunk, the button-board or core, *fig.* 266., is to be placed thereon, with the concave surface

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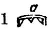

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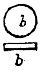

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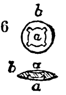

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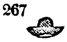

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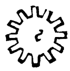

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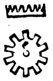

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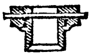

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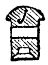

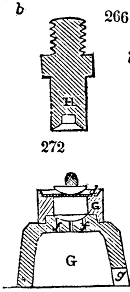

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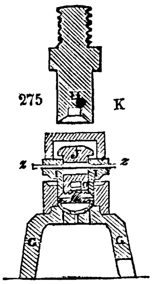

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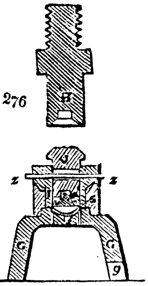

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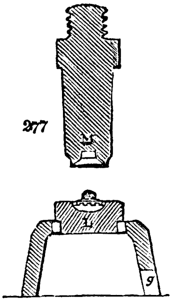

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towards the protruding shank; and the edges of the fabric are then to be pressed over the core, (as is well understood,) which will produce the partly formed button, *fig.* 267., which is a side view, and consists of the shank containing the core, which is next inserted into the metal shell *c*, *fig.* 268., and these parts being placed in a suitable die, are pressed together, and the partly manufactured button, *fig.* 269., will be produced, consisting of the shank containing the core, covered on the front surface with the metal shell *c*, which, by the die, has its edges bent down on the fabric of the flexible shank. The button, thus far formed, is now in a condition to be covered with a thin plate of horn, which is performed in the following manner:—*d*, *fig.* 270., shows a disc of horn, cut out by suitable dies, the circumference being scolloped, in order that in folding over the mould, *fig.* 269., the horn may not be puckered. *e e*, *fig.* 271., shows a collet, for affixing the covering of horn to the button, the collet being similar to that used in what is called "Sandar's plan of making Florentine and other covered buttons."

The method of covering the mould of the button with horn is described as follows: *Fig.* 272. represents, in section, a lower covering die, and also a proper punch for pressing the parts into the lower die; these dies being in a suitable press, as is well understood. The lower die is to be kept heated to such an extent that the workman can just bear his hand to rest, for a very short time, on the upper surface of the die; the heating is preferred to be accomplished by means of a flame of gas below the die; and it will be seen that there are holes *f*, *f*, in the die, through which the heat of the flame may pass; and *g* is an opening, to allow of atmospheric air flowing under the lower die. The disc of horn *d* is placed in the lower die *g*. The shape or mould, *fig.* 269., is then placed on the horn, and the punch or die H is caused to descend, and press the parts into the die *g*; the punch *h* is then raised, in order to allow of the introduction of the parts shown at *figs.* 273 and 274., which consist of the tube I, and the punch or die *j*. The lower edge of the tube I is made bell-mouthed, so as to cause the scolloped edges to be pressed on the back of the buttons, and the die or punch *j* is to cause the collet to be forced through the horn in the button; and, in using these parts, the collet is placed in the tube I, which with its punch is inserted into the die *s*, as shown at *fig.* 275., which figure represents the die *g*, and punch *h*, in the condition just described, after having forced the parts into the die G; and this figure also shows the tube I, with a collet *d* and the punch or die J, placed in the tube I; and all things are in a condition to receive the pressure of the punch H. In order to prevent the pressure coming on the punch or die J, before the horn has been folded down by the tube I, the hollow block K is placed over the die or punch J; consequently when the punch H is caused to descend, it will force down the tube I, and cause it to gather the edges of the horn, and press them on the back of the mould of the button, when the punch H will be raised again, and the block K removed, which will leave all things in the position shown at *fig.* 276.; and then again, the bringing down of the punch H will cause the die or punch J to descend and force the collet into the button, the die J being retained in the tube I by means of the pin *z*, passing through a slit formed therein, which allows of the die J rising and falling in the tube I, but prevents its coming out of that tube. The button, thus far formed, is now in a condition to be completed in the finishing dies, *fig.* 277.; the lower dies being kept heated in a similar manner to the die G. The dies being fixed in a suitable press the button to be finished is inserted into the die L, (which may be ornamented or plain,) with the shank upwards, and the punch or die M is caused to descend and press the button into shape.

When the front of the button is to be plain, the disc of horn should be polished before being used for covering; but when used to cover a button, and finished by an engraved or ornamented die, the polishing is not necessary. The button being thus made is to be finished by placing it in a lathe to be "edged," as is commonly practised in finishing horn buttons.

The patentee does not claim the means of making the mould or shape shown at *fig.* 269., nor the dies employed when separately considered, very similar dies having been before used in the manufacture of other covered buttons; nor does he confine himself thereto, so long as the peculiar character and essence of the invention be retained; viz. that of manufacturing covered buttons, made by dies and pressure by the application of thin sheet horn as the covering material. He claims the mode herein described, of manufacturing covered buttons by the application of horn as a covering material, as above described.

C.

CABLE. (*Cable*, Fr.; *Ankertau*, Germ.) A strong rope or chain connecting the ship with the anchor for the purpose of mooring it to the ground. The *sheet anchor* cable is the strongest, and is used at sea; the *stream* cable is more slender, being used chiefly in rivers. A cable's length is 120 fathoms. The greatest improvement in mooring vessels has been the introduction of the chain cable, which, when duly let out, affords in the weight of its long catenary curve, an elastic tension and play to the ship under the pressure of the wind. The dead strain upon the anchor is thus greatly reduced, and the sudden pull by which the flukes or arms are readily snapped is in a great measure obviated. The best iron cables are chains made of links, bound and braced by rods across their middle. Experience has taught that the ends of these links wear out much sooner than the sides. To remedy this evil, Mr. Hawkes, iron manufacturer, obtained a patent in July, 1828, for constructing these anchor chains with links considerably stouter at the ends than in the middle. With this view he forms the short rods of iron, of which the links are to be made, with swells or protuberances about one-third of their length from each of their ends, so that when these are welded together, the slenderer parts are at the sides, and the thicker at the ends of the elliptical links. Such rods as the above are formed at once by rolling, swagging, or any other means. When the link is welded, it may be strengthened, by a brace or stretcher fixed across the middle.

The first avowed proposal to substitute iron cables for cordage in the sea service was made by Mr. Slater, surgeon of the navy, who obtained a patent for the plan in 1808, though he does not seem to have had the means of carrying it into effect; a very general misfortune with ingenious projectors. It was Captain Brown, of the West India merchant service, who, in 1811, first employed chain cables in the vessel Penelope, of 400 tons burden, of which he was captain. He made a voyage in this ship from England to Martinique and Guadaloupe and home again, in the course of four months, having anchored many times in every variety of ground without any accident. He multiplied his trials, and acquired certain proofs that iron might be substituted for hemp in making cables, not only for mooring vessels, but for the standing rigging. Since this period chain cables have been universally introduced into all the ships of the royal navy, but the twisted links employed at first by Brown have been replaced by straight ones, stayed in the middle with a cross rod, the contrivance of Mr. Brunton, which was secured by patent in this country and in France; but the latter patent was suffered to fall from not being acted upon within the two years specified by law.

The first thing to be considered in the manufacture of iron cable is, to procure a material of the best quality, and, in using it, always to keep in view the direction of the strain, in order to oppose the maximum strength of the iron to it. The best form of the links may be deduced from the following investigation.

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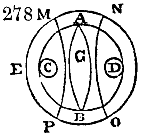

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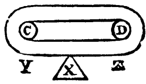

Let A B, *fig.* 278., be a circular link or ring, of one inch rod iron, the outer circumference of the ring being 15 inches, and the inner 9. If equal opposite forces be applied to the two points of the link C D, pulling C towards E, and D towards F, the result will be, when the forces are sufficiently intense, that the circular form of the link will be changed into another form with two round ends and two parallel sides, as seen in *fig.* 279. The ratio of the exterior to the interior periphery, which was originally as 15 to 9, or 5 to 3, is no longer the same in *fig.* 279. Hence there will be a derangement in the relative position of the component particles, and consequently their cohesion will be progressively impaired, and eventually destroyed. In *fig.* 278. the segment M N of the outside periphery being equal to 3 inches, the corresponding inside segment will be $\frac{3}{5}$ of it, or $1\frac{4}{5}$ inches. If this portion of the link, in consequence of the stretching force, comes to be extended into a straight line, as shown in *fig.* 279, the corresponding segments, interior and exterior, must both be reduced to an equal length. The matter contained in the 3 inches of the outside periphery must therefore be either compressed, that is, condensed into $1\frac{4}{5}$ inches, or the inside periphery, which is only $1\frac{4}{5}$ inches already, must be extended to 3 inches; that is to say, the exterior condensation and the interior expansion must take place in a reciprocal proportion. But, in every case, it is impossible to effect this contraction of one side of the rod, and extension of the other, without disrupture of the link.

Let us imagine the outside periphery divided into an infinity of points, upon each of which equal opposite forces act to straighten the curvature: they must undoubtedly occasion the rupture of the corresponding part of the internal periphery. This is not the sole injury which must result; others will occur, as we shall perceive in considering what passes in the portion of the link which surrounds C D, *fig.* 279, whose length is $4\frac{1}{2}$ inches outside, and $2\frac{1}{10}$ inside. The segments M P and N O, *fig.* 278 are actually reduced to semi-circumferences, which are inside no more than half an inch, and outside as before. There is thus contraction in the interior, with a quicker curvature or one of shorter radius in the exterior. The derangement of the particles takes place here, in an order inverse to that of the preceding case, but it no less tends to diminish the strength of that portion of the link; whence we may certainly conclude that the circular form of cable links is an extremely faulty one.

Leaving matters as we have supposed in *fig.* 278, but suppose that G is a rod introduced into the mail, hindering its two opposite points A B from approximating. This circumstance makes a remarkable change in the results. The link pulled as above described, must assume the quadrilateral form shown in *fig.* 280. It offers more resistance to deformation than before; but as it may still suffer change of shape, it will lose strength in so doing, and cannot therefore be recommended for the construction of cables which are to be exposed to very severe strains.

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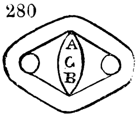

Supposing still the link to be circular, if the ends of the stay comprehended a larger portion of the internal periphery, so as to leave merely the space necessary for the plan of the next link, there can be no doubt of its opposing more effectively the change of form, and thus rendering the chain stronger. But, notwithstanding, the circular portions which remain between the points of application of the strain and the stay, would tend always to be straightened, and of consequence to be destroyed. Besides, though we could construct circular links of sufficient strength to bear all strains, we ought still to reject them, because they would consume more materials than links of a more suitable form, as we shall presently see.

The effect of two opposite forces applied to the links of a chain, is, as we have seen, to reduce to a straight line or a straight plane every curved part which is not stayed: whence it is obvious that twisted links, such as Brown first employed, even with a stay in their middle, must of necessity be straightened out, because there is no resistance in the direction opposed to the twist. A cable formed of twisted links, for a vessel of 400 tons, stretches 30 feet, when put to the trial strain, and draws back only 10 feet. This elongation of 20 feet proceeds evidently from the straightening of the twist in each link, which can take place only by impairing the strength of the cable.

From the preceding remarks, it appears that the strongest links are such as present, in their original form, straight portions between the points of tension; whence it is clear that links with parallel sides and round ends would be preferable to all others, did not a good cable require to be able to resist a lateral force, as well as one in the direction of its length.

Let us suppose that by some accident the link *fig.* 279. should have its two extremities pulled towards Y and Z, whilst an obstacle X, placed right opposite to its middle, resisted the effort. The side of the link which touches X would be bent inwards; but if, as in *fig.* 281., there is a stay A G B, the two sides would be bent at the same time; the link would notwithstanding assume a faulty shape.

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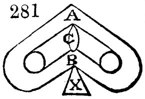
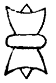


In thus rejecting all the vicious forms, we are naturally directed to that which deserves the preference. It is shown in *fig.* 282. This link has a cast-iron stay with large ends; it presents in all directions a great resistance to every change of form; for let it be pulled in the direction *a b*, against an obstacle *c*, it is evident that the portions *d e* and *d f*, which are supported by the parts *g e* and *g f*, cannot get deformed or be broken without the whole link giving way. As the matter composing *g e* and *g f* cannot be shortened, or that which composes *d e* and *d f* be lengthened, these four sides will



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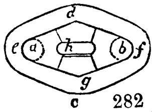

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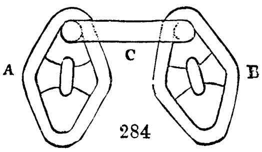
remain necessarily in their relative positions, by virtue of the large-ended stay *h*, whose profile is shown in *fig.* 283.



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We have examined the strength of a link in every direction, except that perpendicular to its plane. *Fig.* 284. represents the assemblage of three links in the above predicament; but we ought to observe, that the obstacle C, placed between the links A B, must be necessarily very small, and could not therefore resist the pressure or impact of the two lateral links.

Process of manufacturing iron cables.—The implements and operations are arranged in the following order:—

1. A reverberatory furnace (see Iron), in which a number of rods or round bars of the best possible wrought-iron and of proper dimensions, are heated to bright ignition.
2. The cutting by a machine of these bars, in equal lengths, but with opposite bevels, to allow of the requisite crossing and slicing of the ends in the act of welding.
3. The bending of each of these pieces by a machine, so as to form the links; the last two operations are done rapidly while the iron is red-hot.
4. The welding of the links at small forge fires, fitted with tools for this express purpose, and the immediate introduction of the stay, by means of a compound lever press.
5. Proving the strength of the cables by an hydraulic press, worked by two men turning a winch furnished with a fly wheel.

The furnace is like those used in the sheet-iron works, but somewhat larger, and needs no particular description here.

Figs. 285. and 286. are a plan and elevation of the shears with which the rods are cut into equal pieces for forming each a link. It is moved at Mr. Brunton's factory by a small steam engine, but, for the sake of simplicity, it is here represented worked by four or more labourers, as it may be in any establishment. These must be relieved however frequently by others, for I believe each shears' machine is calculated to require nearly one horse in steam power. It is portable and must be placed in the neighbourhood of both the furnace and bending machine.

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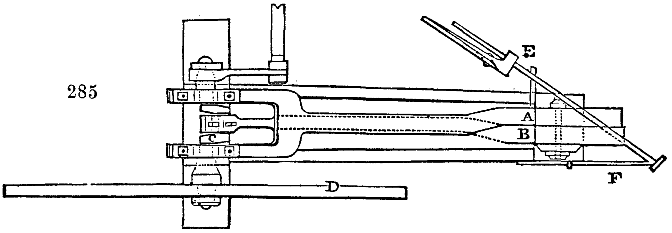

A and B are the two cast-iron limbs of the shears. The first is fixed and the second

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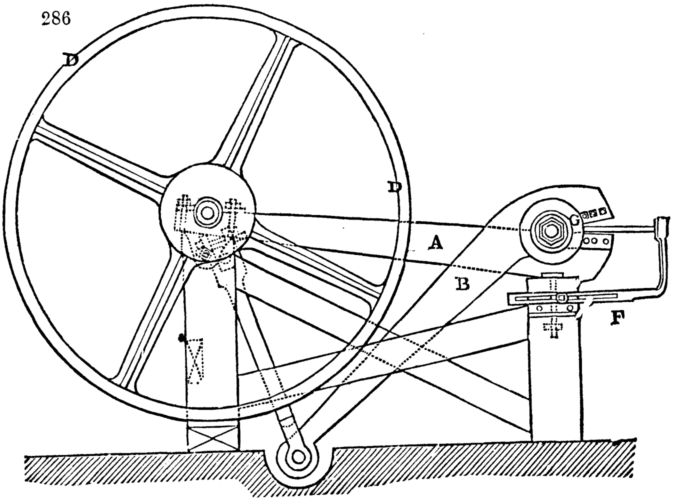

is moveable by means of a crank shaft C, driven by a heavy fly-wheel weighing 7 or 8 cwt.

The cutting jaws G are mounted with pieces of steel which are made fast by bolts, and may be changed at pleasure.

E, the bar of iron to be cut. It is subjected, immediately upon being taken out of the fire, to the shears, under a determinate uniform angle, care being taken not to let it turn round upon its axis, lest the planes of the successive incisions should become unequal.

F is a stop which serves to determine, for the same kind of chain, the equality of length in the link pieces.

Figs. 287, 288, 289, plan and elevations of the machine for bending the links into an elliptic form. It is represented at the moment when a link is getting bent upon it.

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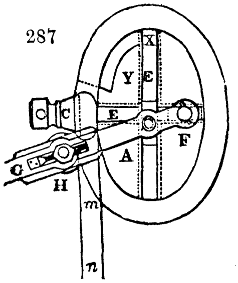

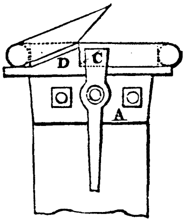

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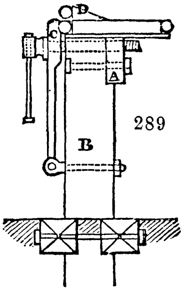

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A is an elliptic mandrel of cast-iron; it is fixed upon the top of a wooden pillar B, solidly supported in the ground. C is the jaw of the vice, pressed by a square-headed screw against the mandrel A.

D part of the mandrel comprehended between X and Y, formed as an inclined plane, so as to preserve an interval equal to the diameter of the rod between the two surfaces that are to be welded together.

E rectangular slots (shears) passing through the centre of the nut of the mandrel, in which each of the pins F may be freely slidden.

G horizontal lever of wrought-iron six feet long. It carries at H a pulley or friction-roller of steel, whose position may be altered according to the diameter of the links. It is obvious that as many mandrels are required as there are sizes and shapes of links.

The piece of iron intended to form a link being cut, is carried, while red-hot, to the bending machine, where it is seized with the jaw of the vice C, by one of its ends, the slant of the cut being turned upwards; this piece of iron has now the horizontal direction *m n;* on pushing the lever G in the line of the arrow, the roller H will force *m n* to be applied successively in the elliptic groove of the mandrel: thus finally the two faces that are to be welded together will be placed right opposite each other.

The length of the small diameter of the ellipse ought to exceed by a little the length of the stay-piece, to allow of this being readily introduced. The difference between the points F, E, is equal to the difference of the *radii vectores* of the ellipse. Hence it will be always easy to find the eccentricity of the ellipse.

Fig. 290 is a lever press for squeezing the links upon their stays, after the links are

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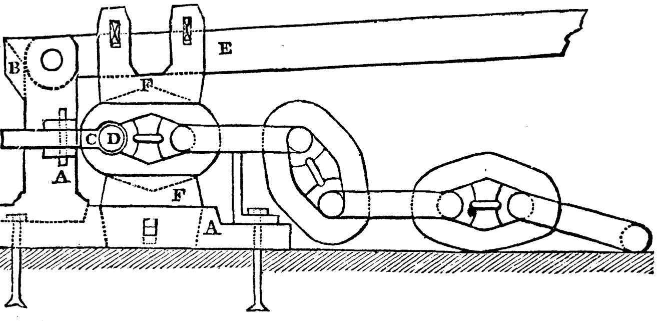

welded. This machine consists of a strong cast-iron piece A, in the form of a square, of which one of the branches is laid horizontally, and fixed to a solid bed by means of bolts; the other branch, composed of two cheeks, leaving between them a space of two inches, stands upright. These two cheeks are united at top, and on the back of their plane by a cross piece B. C, a rectangular staple, placed to the right and left of the cheeks through which is passed the mandrel D, which represents and keeps the place of the following link. E, is a press lever, 6 feet long. F, clamp and counterclamp, between which the link is pressed at the moment when the stay is properly placed. There are other clamps, as well as staples C, for changing with each changed dimension of links.

The links bent, as we have seen, are carried to the forge hearth to be welded, and to receive their stay; two operations performed at one heating. Whenever the welding is finished, while the iron is still red-hot, the link is placed upright between the clamps F; then a workman introduces into the staple the mandrel D, and now applies the stay with a pair of tongs or pincers, while another workman strikes down the lever E forcibly upon it. This mechanical compression first of all joins perfectly the sides of the link against the concave ends of the stay, and afterwards the retraction of the iron on cooling increases still more this compression.

If each link be made with the same care, the cable must be sound throughout. It is not delivered for use, however, till it be proved by the hydraulic press, at a draw-bench made on purpose. The press is a horizontal one, having the axis of its ram in the middle line of the draw-bench, which is about 60 feet long, and is secured to the body of the press by strong bolts.

The portion of chain under trial, being attached at the one end to the end of the ram of the press, and at the other to a cross-bar at the extremity of the draw-bench, two men put the press in action, by turning the winch, which works by a triple crank three forcing pumps alternately; the action being equalized by means of a heavy fly-wheel. As long as the resistance does not exceed the force of two men, the whole three pumps are kept in play. After a while one pump is thrown out of gear and next another, only one being worked towards the conclusion. The velocity of the ram being retarded first one third and next two thirds, gives the men a proportional increase of mechanical power.

The strength of two average men thus applied being computed, enables us to know at every instant the resistance opposed by the chain to the pressure of the ram. The strain usually applied to the stronger cables is about 500 tons.

The side beams of the draw-bench are of cast-iron, 6 inches in diameter; the different pieces composing it are adjusted to each other endwise by turned joints. Props also of cast-iron support the beams two feet asunder, and at the height of 30 inches above the ground. The space between them is filled with an oak plank on which the trial chain is laid.

Strength of iron cables compared to hemp cables:—

Iron Cables. Diameter of Iron Rod.	Hemp Cables. Circumference of Rope.	Resistance.
Inches.	*Inches.*	*Tons.*
$0\frac{7}{8}$	9	12
1	10	18
$1\frac{1}{8}$	11	26
$1\frac{1}{4}$	12	32
$1\frac{5}{16}$	13	35
$1\frac{3}{8}$	14 to 15	38
$1\frac{1}{2}$	16	44
$1\frac{5}{8}$	17	52
$1\frac{3}{4}$	18	60
$1\frac{7}{8}$	20	70
2	22 to 24	80

It would be imprudent to put hemp cables to severer strains than those indicated in the preceding table, drawn up from Brunton's experiments; but the iron cables of the above sizes will support a double strain without breaking. They ought never in common cases, however, to be exposed to a greater stress. A cable destined for ships of a certain tonnage, should not be employed in those of greater burden. Thus treated it may be always trusted to do its duty, and will last longer than the ship to which it belongs. A considerable part of this decided superiority which iron cables have over hemp ones, is undoubtedly due to the admirable form contrived by Brunton. Repeated experiments have proved that his cables possess double the strength of the iron rods with which they are made — a fact which demonstrates that no stronger form can be devised or is in fact possible.

One of the most valuable qualities of iron cables is their resisting lateral as well as longitudinal strains, as explained under *figs.* 282 and 284.

Vessels furnished with such cables have been saved by them from the most imminent

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peril. The Henry, sent out with army stores during the peninsular war, was caught on the northern coast of Spain in a furious storm. She run for shelter into the Bay of Biscay among the rocks, where she was exposed for three days to the hurricane. She possessed fortunately one of Brunton's 70 fathom chain cables, which held good all the time, but it was found afterwards to have had the links of its lower portion polished bright by attrition against the rocky bottom. A hemp cable would have been speedily torn to pieces in such a predicament.

In the contracts of the Admiralty for chain cables for the British navy, it is stipulated that "the iron shall have been manufactured in the best manner from pig iron, smelted from iron-stone only, and selected of the best quality for the purpose, and shall not have received, in any process whatever subsequent to the smelting, the admixture of either the cinder or oxydes produced in the manufacture of iron; and shall also have been puddled in the best manner upon iron bottoms, and at least three times sufficiently drawn out at three distinct welding heats, and at least twice properly fagoted."

The following is a table of the breaking proof of chain cables, and of the iron for the purpose of making them, also of the proofs required by her majesty's navy for chains.

Size of Bolt.	Proof of Bolt.		Proof of Chain.		Navy Proof of Chain.
Inches.	*Tons.*	*Cwt.*	*Tons.*	*Cwt.*	*Tons.*
½	5	7	8	11	4½
⅝	8	7	13	4	5½
¾	12	1	19	5	10⅞
⅞	16	4	26	5	13¾
1	21	8	34	5	18
1⅓	27	2	48	15	22¾
1¼	33	10	53	11	28½
1⅜	40	10	65	0	34
1½	48	4	77	0	40½
1⅝	56	11	90	10	47½
1¾	65	12	105	0	55⅛
1⅞	75	6	120	10	63¼
2	85	14	137	0	72
2⅛	96	15	155	0	81¼

In Brunton's cable the matter in the link is thrown very much into one plane; the link being of an oval form, and provided with a stay. As there are emergencies in which the cable must be severed, this is accomplished in those of iron by means of a bolt and sheckle (shackle), at every fathom or two fathoms; so that by striking out this bolt or pin, this cable is parted with more ease than a hempen one can be cut.

CACAO, BUTTER OF. See Cocoa, and Oils, Unctuous.

CADMIUM is a metal discovered about the beginning of the year 1818. It occurs chiefly in Silesia in several ores of zinc; and may be readily recognised by means of the blowpipe; for at the first impression of the reducing or smoky part of the flame, the ores containing cadmium stain the charcoal all round them with a reddish yellow circle of oxyde of cadmium. The Silesian native oxyde of zinc contains from 1½ to 11 per cent. of cadmium.

The cadmium may be extracted by dissolving the ore in sulphuric acid, leaving the solution acidulous, and diluting it with water, then transmitting through it a stream of sulphureted hydrogen, till the yellow precipitate ceases to fall. This powder, which is sulphuret of cadmium, is to be dissolved in concentrated muriatic acid, the excess of which is to be expelled by evaporation; and the muriatic salt being dissolved in water, carbonate of ammonia is to be added in excess, whereby the cadmium separates as a carbonate, while the small portion of adhering copper or zinc is retained in solution by the ammonia. Herapath has shown, that in distilling zinc *per descensum* (see Zinc), the first portions of gaseous metal which are disengaged burn with a brown flame and deposite the brown oxyde of cadmium.

Cadmium has the color and lustre of tin, and is susceptible of a fine polish. Its fracture is fibrous; it crystallizes readily in regular octahedrons, and when it suddenly solidifies, its surface gets covered with fine mossy vegetations. It is soft, easily bent, filed, and cut, soils like lead any surface rubbed with it. It is harder and more tenacious than tin, and emits a creaking sound when bent, like that metal. It is very ductile, and may be drawn out into fine wire, and hammered into thin leaves without cracking at the edges. Its specific gravity, after being merely melted, is 8·604; and 8·6944 after it has been hammered. It is very fusible, melting at a heat much under redness; indeed, at a temperature little exceeding that of boiling mercury, it boils and distils over in drops. Its vapors have no smell. It is but slightly altered by exposure to air. When heated in the atmosphere, it readily takes fire, and burns with a brownish yellow smoke which is destitute of smell. In strong acids it dissolves with disengagement of hydrogen, and forms colourless solutions. Chromate of potash causes no precipitate in them, unless zinc or lead be present.

There is only one oxide of cadmium, the brown above mentioned. Its specific gravity is 8·183. It is neither fusible nor volatile at a very high temperature. When in the state of a hydrate it is white. The oxide of cadmium consists of 87·45 parts of metal, and 12·55 oxygen in 100 parts. Berzelius states its atomic weight to be 55·833 to hydrogen 1·000. Its sulphuret has a fine orange yellow colour, and would form a beautiful pigment, could the metal be found in sufficient quantity for the purposes of art. The sulphate is applied to the eyes by surgeons for removing specks of the cornea.

CAFFEINE. A chemical principle discovered in coffee, remarkable for containing much azote. See Coffee.

According to Robiquet the proportion of caffeine in 1000 of coffee is as follows:

Martinique 6·4, Alexandrian 4·4, Java 4·4, Mocha 4, Cayenne 3·8, St. Domingo 3·2. It is probable that 0·64 per cent. is an ordinary proportion. According to Liebig, the proportions are per lb., Martinique 32 gr., Alexandrian 22, Java 22, Mocha 20, Cayenne 19, St. Domingo 16. H. J. Versman of Lubeck mixes 10 lbs. of bruised raw coffee with 2 of caustic lime, made previously into hydrate; treats the mixture in a displacement apparatus with alcohol of 80° till the fluid which passes through no longer furnishes evidence of the presence of caffeine. The coffee is then roughly ground and brought nearly to the state of a powder, and the refuse of the once digested mixture from the displacement apparatus, dried and ground again, and mixed with hydrate of lime, is once more macerated. The grinding is more easily effected after the coffee has been subjected to the operation of alcohol, having lost its horny quality, and the caffeine is thus more certainly extracted. The clear alcoholic liquid thus obtained is then to be distilled, and the refuse in the retort to be washed with warm water, to separate the oil. The fluid is now evaporated into a crystalline mass, filtered and expressed. The impure caffeine is freed from oil by pressure between folds of blotting paper, purified by solution in water with animal charcoal, and is thus obtained in shining white silky crystals. In general not more than 3 drams were procured from 5 pounds of coffee, from 10 pounds 7 drams, and from 100 pounds the largest quantity, viz. 6 ounces and 4 scruples of caffeine; a proof that a large quantity must be operated upon, if in a quantitative respect a satisfactory result is to be obtained. Thus it is seen that good Brazilian coffee contains 0·57 per cent. of caffeine. At the same time it may be observed that it contains about 10 per cent. of a green liquid oil, and 2 per cent. of a yellow solid fat.

CAJEPUT OIL is obtained from the leaves of the tree called Melaleuca Leucadendron by Linnæus, which grows upon the mountains of Amboyna, and in other of the Molucca islands. It is procured by distillation of the dried leaves along with water, is prepared in great quantities in the island of Banda, and sent to Holland in copper flasks. Hence as it comes to us, it has a green colour. It is very limpid, lighter than water, of a strong smell resembling camphor, and pungent taste like cardamoms. When rectified the copper remains in the retort, and the oil comes over colourless. It is used in medicine as a stimulant. See Oils, Ethereous.

CALAMANCO. A sort of woollen stuff of a shining appearance, chequered in the warp, so that the checks are seen only upon one side.

CALAMINE. A native carbonate of zinc. See Zinc.

CALCAREOUS EARTH. (*Terre calcaire*, Fr.; *Kalkerde*, Germ.) Commonly denotes lime, in any form; but, properly speaking, it is pure lime.

CALCAREOUS SPAR. Crystallized native carbonate of lime.

CALCEDONY. A hard mineral of the siliceous family, often cut into seals. Under it may be grouped common calcedony, heliotrope, chrysoprase, plasma, onyx, sardonyx, and sard.

CALCHANTUM. The ancient name of native copperas or sulphate of iron.

CALCINATION, is the chemical process of subjecting metallic bodies to heat with access of air, whereby they are converted into a pulverulent matter, somewhat like lime in appearance, called *calx* in Latin. The term calcination, however, is now used when any substance whatever is exposed to a roasting heat.

CALCIUM. The metallic basis of lime. See Lime.

The atomic weight of this element being an important point, both as to pure chemistry and the chemical arts, has been the subject of innumerable researches. Very lately Berzelius, in the *Annalen der Chemie und Pharmacie*, XLVI. p. 241., has collated the most recent results of the analysis of other philosophers with his own; and while Dumas, Marchand, and Erdmann estimate the weight at 20, that of hydrogen = 1, or 250 oxygen = 100, he finds it ought to be, as compared with the latter, 2519; and to the former, 20,152.

CALC-SINTER. The incrustations of carbonate of lime upon the ground, or the pendulous conical pieces called stalactites, attached to the roofs of caverns, are so called.

CALC-TUFF. A semi-hard, irregular deposite of carbonate of lime, formed from the waters of calcareous springs.

CALCULUS. The stony-looking morbid concretion, occasionally formed in the bladder of urine, gall-bladder, cystic duct, kidneys, and other parts of living animals. Its examination belongs to medical chemistry.

CALENDER (*Calandre*, Fr.; *Kalander*, Germ.), a word derived from the Greek *kalindros* (cylinder), is the name of a machine, consisting of two or more cylinders, revolving so nearly in contact with each other that cloth passed through between them is smoothed, and even glazed, by their powerful pressure. It is employed either to finish goods for the market, or to prepare cotton and linen webs for the calico-printer, by rendering their surfaces level compact, and uniform. This condensation and polish, or *satinage*, as the French call it, differ in degree according to the object in view, and may be arranged into three distinct series. 1. For goods which are to receive the first impression by the block, a very strong pressure is required; for, upon the uniformity of the polish, the neatness and regularity of the printing, and the correspondence of its members, depend. In many establishments the calico is passed twice through the calender before being sent to the tables. 2. The pieces already dyed up at the madder bath, or otherwise, and which remain to be filled in with other colors, or *grounded-in*, as it is technically styled, must receive a much less considerable gloss. This is a principle everywhere admitted and acted upon, because the outline of the figured design being deranged by the washing, and sometimes in consequence of the peculiar texture of the cloth, the printer, in order to apply his grounding blocks properly, and to fit them to the contours of the figures already impressed, is obliged to stretch the piece sometimes in the direction of the warp, and sometimes of the weft, which would be impossible if they had been hard glazed by the calender. 3. The degree of glazing given to finished goods depends upon the taste of purchasers, and the nature of the article; but it is, in general, much less than for the first course of block-printing.

The most complete calender probably in existence is that used by some of the eminent calico-printers of Alsace, as contrived by M. Charles Dollfus, and constructed by MM. Witz, Blech, and Co. 1. It passes two pieces at once, and thus does double the work of any ordinary machine. 2. It supersedes the necessity of having a workman to fold up the goods, as they emerge from the calender, with the aid of a self-acting folder. 3. It receives, at pleasure, the finished pieces upon a roller, instead of laying them in folds; and, by a very simple arrangement, it hinders the hands of the workmen from being caught by the rollers.

Calenders, in consequence of the irregular demand for foreign orders and shipments, are worked very irregularly, being sometimes overloaded with duty, and at others altogether unemployed. A machine which can, when required, turn out a double quantity of goods, must, therefore, be a desirable possession. For the first course of the printers, where high calendering is necessary, the goods are usually passed twice through between two paper cylinders, to give that equality of surface which could not be obtained by one passage, however strong the pressure; and therefore the simplification of this calender will prove no economy. Besides, in order to increase the pressure to the requisite degree, the cylinders would need to be made bulging at their middle part, and with such cylinders common smoothing could not be given; for the pieces would be glazed in the central line, and rough towards the edges. For pieces already printed in part, and requiring only to be grounded-in for other colors, the system of double effect has fewer objections, as a single passage through the excellent calender described under BLEACHING, page 140, is found to answer very well.

The most remarkable feature of M. Dollfus's machine is its being managed by a single workman. Six or eight pieces are coiled upon the feed-roller, and they are neither pasted nor stitched together, but the ends are merely overlapped half a yard or so. The workman is careful not to enter the second piece till one third or one half of the first one has passed through on the other side, to prevent his being engrossed with two ends at a time. He must, no doubt, go sometimes to the one side, and sometimes to the other of the machine, to see that no folds or creases occur, and to be ready for supplying a fresh piece as the preceding one has gone through. The mechanism of the folder in the Alsace machine is truly ingenious: it performs extremely well, really saves the attendance of an extra workman, and is worthy the attention of manufacturers intent upon economizing hand labor. The lapping-roller works by friction, and does its duty fully better than similar machines guided by the hand.

The numerous accidents which have happened to the hands of workmen engaged in calenders should direct the attention towards its effective contrivance for preventing such misfortunes. These various improvements in the Alsace machine may be easily adapted to the ordinary calenders of almost every construction.

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The folder is a kind of cage, in the shape of an inverted pyramid, shut on the four sides, and open at top and bottom; the top orifice is about five inches, the bottom one an inch and a half; the front and the back, which are about four feet broad, are made of tin-plate or smooth pasteboard, and the two sides are made of strong sheet-iron; the whole being bolted together by small bars of iron. Upon the sheet-iron of the sides, iron uprights are fixed, perforated with holes, through which the whole cage is supported freely by means of studs that enter into them. One of the uprights is longer than the other, and bears a slot with a small knob, which, by means of the iron piece, joins the guide to the crank of the cylinder, and thereby communicates to the cage a seesaw movement; at the bottom extremity of the great upright, there is a piece of iron in the shape of an anchor, which may be raised, or lowered, or made fast, by screws.

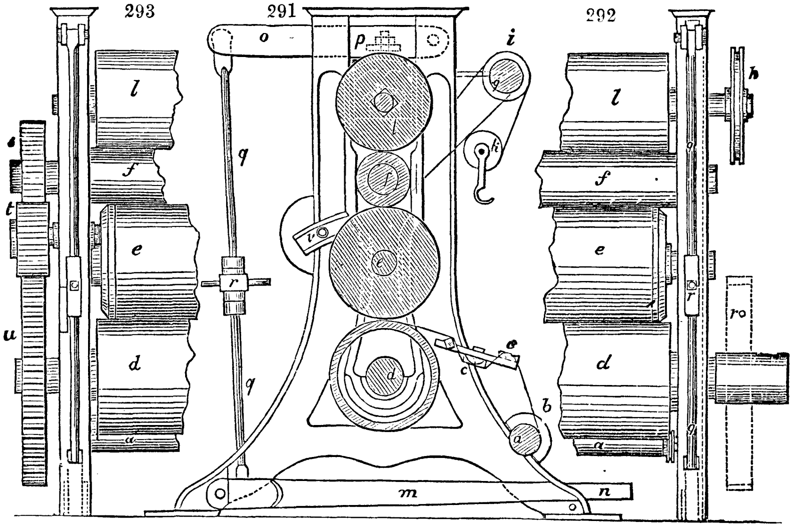
At the ends of this anchor are friction-rollers, which may be drawn out or pushed back and fixed by screws; these rollers lift alternately two levers made of wood, and fixed to a wooden shaft.

The paws are also made of wood: they serve to lay down alternately the plies of the cloth which passes upon the cage, and is folded zigzag upon the floor, or upon a board set below the cage; a motion imparted by the seesaw motion of the cage itself. See STRETCHING MACHINE.

To protect the fingers of the workmen, above the small plate of the spreading-board or bar, there is another bar, which forms with the former an angle of about 75°; they come sufficiently near together for the opening at the summit of the angle to allow the cloth to pass through, but not the fingers. See *Bulletin de la Société Industrielle de Mulhausen*, No. 18.

I shall now describe, more minutely, the structure of the powerful but less complicated calender mechanisms employed in the British manufactories.

A front elevation of a four-rollered calender (five rollers are often introduced) for glazing goods is given in *fig.* 293. *d l* are two pasteboard or paper cylinders, each 20 inches in diameter, whose structure will be presently described: *f* is a cast-iron cylinder turned perfectly smooth (its fellow is often placed between *e* and *d*): it is eight inches in diameter outside, four inches inside, with two inches thickness of metal. *e* is another pasteboard cylinder, fourteen inches in diameter: the strong cast-iron frame contains the bushes in which the journals of the rollers turn. *o p*, is one of the pair of levers for communicating a graduated pressure according to the quality of the goods. *Figs.* 292, 293, are end views of the same machine to show the working gear. The wheel *s*, on the end of the upper iron cylinder, is ten inches in diameter; that on the end of the fellow iron cylinder below (when it is present) is thirteen inches; both are connected by the larger carrier wheel *t*. The lower wheel *u* is one third larger than the upper wheel, and therefore receives from the carrier wheel *t*, a proportionally slower motion, which it imparts to the central pasteboard roller *e*, lying upon it, causing it to move one third more slowly than the upper pasteboard roller. Thus a sort of sliding motion is produced, which, by rubbing their surfaces, glazes the goods.


293 291 292

The iron rollers are made hollow for the purpose of admitting either a hot roller of iron, or steam when hot calendering is required. The other cylinders used formerly to be made of wood, but it was liable to many defects. The advantage of the paper roller consists in its being devoid of any tendency to split, crack, or warp, especially when exposed to a considerable heat from the contact and pressure of the hot iron rollers. The paper, moreover, takes a vastly finer polish, and, being of an elastic nature, presses into every pore of the cloth, and smooths its surface more effectually than any wooden cylinder, however truly turned, could possibly do.

The paper cylinder is constructed as follows:—The axis of the cylinder is a strong square bar of the best wrought iron, cut to the proper length. Upon this bar a strong round plate of cast iron is first put, somewhat less in diameter than the cylinder when finished. A quantity of thick stout pasteboard is then procured, and cut into round pieces an inch larger in diameter than the iron plate. In the centre of the plates, and of every piece of the pasteboard, a square hole must be cut to receive the axis; and, the circle being divided into six equal parts, a hole must also be cut at each of the divisions, an inch or two within the rim. These pieces of pasteboard being successively put upon the axis, a long bolt of malleable iron, with a head at one end, and screwed at the other, is also introduced through each of the holes near the rim; and this is continued until a sufficient number of pasteboards are thus placed to form a cylinder of the length required, proper allowance being made for the compression which the pasteboard is afterwards to undergo. Another round plate is then applied, and, nuts being put upon the screws, the whole are screwed tight, and a cylinder formed. This cylinder is now to be placed in a stove, exposed to a strong heat, and must be kept there for at least several days; and, as the pasteboard shrinks by exposure to the heat, the screws must be frequently tightened until the whole mass has been compressed as much as possible. When the cylinder is thus brought to a sufficient degree of density, it is removed from the stove; and, when allowed to cool, the pasteboard forms a substance almost inconceivably dense and hard. Nothing now remains but to turn the cylinder; and this is an operation of no slight labor and patience. The motion in turning must be slow, not exceeding about forty revolutions in a minute; the substance being now so hard and tough that tools of a very small size must be used to cut, or rather scrape it, until it is true. Three men are generally employed for the turning, even when the motion of the cylinder is effected by mechanical power, two being necessary to sharpen tools for the third, who turns, as quickly as he blunts them.

Let us suppose it to be a five-rollered machine: when a person stands in front of the calender, the cloth coming from behind above the uppermost cylinder 1, passes between 1 and 2: proceeding behind 2, it again comes to the front between 2 and 3: between 3 and 4 it is once more carried behind, and, lastly, brought in front between 4 and 5, where it is received, and smoothly folded on a clean board, or in a box, by a person placed there for the purpose. In folding the cloth at this time, care must be taken that it may be loosely done, so that no mark may appear until it be again folded in the precise length and form into which the piece is to be made up. The folding may be done either by two persons or by one, with the aid of two sharp polished spikes placed at a proper distance, to ascertain the length of the fold, and to make the whole equal. When folded into lengths, it is again folded across upon a smooth clean table, according to the shape intended, which varies with the different kinds of goods, or the particular market for which the goods are designed.

When the pieces have received the proper fold, the last operation previous to packing them is the pressing. This is commonly performed by placing a certain number of pieces, divided by thin smooth boards of wood, in a common screw press, similar to those used by printers for taking out the impression left by the types in the printing-press. Besides the wooden boards, a piece of glazed pasteboard is placed above and below every piece of cloth, that the outer folds may be as smooth and glossy as possible. The operation of the common screw press being found tedious and laborious, the hydraulic press is now in all well-mounted establishments had recourse to. See HYDRAULIC PRESS.

No improvements that have taken place in calendering can exceed the power and facility of the water press: one of these presses may be worked by two men, who can with great ease produce a pressure of 400 tons; but, in considerable establishments, the presses are worked by power. See BANDANNA.

The appearance and finish of the goods, in consequence of such an immense weight acting on them, are materially improved.

The press is also used for the purpose of packing; whereby the bale is rendered much more compact than formerly. It is commonly roped, &c., while in this compressed state; the dimensions are therefore greatly diminished from what they would otherwise be by any other method. For instance, the same quantity of goods packed in a bale are from one third to one half less bulky than if they were packed in a box with the utmost force of the hands.

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For lawns and muslins of a light texture, the operation of smoothing requires a different process in some respects than close heavy fabrics. They only require to be slightly smoothed to remove any marks which they may have received at the bleaching; and as their beauty depends rather on their transparency than their closeness, the more the cylyndrical form of the yarn is preserved the better. They are therefore put through a small machine, consisting of three rollers or cylinders; and as the power required to move this is small, the person who attends it generally drives it by a small winch; or the same effect may be produced by passing the muslins between only two or three rollers of the above calender, lightly loaded.

In the thick fabrics of cloth, including those kinds which are used for many parts of household furniture, as also those for female dress, the operation of glazing is used both to add to the original beauty of the cloth, and to render it more impervious to dust or smoke. The glazing operation is performed entirely by the friction of any smooth substance upon the cloth; and, to render the gloss brighter, a small quantity of bleached wax is previously rubbed over the surface. The operation of glazing by the common plan is very laborious, but the apparatus is of the most simple kind. A table is mounted with a thick stout cover of level and well-smoothed wood, forming an inclined plane; that side where the operator stands at work being the lowest. The table is generally placed near a wall, both for convenience in suspending the glazing apparatus, and for the sake of light. A long piece of wood is suspended in a groove formed between two longitudinal beams, placed parallel to the wall, and fixed to it. The groove resembles exactly the aperture between the shears of a common turning lathe. The lever, of which the groove may be supposed to be the centre or fulcrum, is faced at the bottom with a semi-cylindrical piece of finely polished flint, which gives the friction to the cloth stretched upon the table below. Above the flint are two cross handles, of which the operator lays hold, and moves them backward and forward with his hands, keeping the flint pressing slightly upon the cloth. When he has glazed a portion equal to the breadth of the flint, he moves his lever between the shears sidewise, and glazes a fresh part: thus he proceeds from one side or selvage of the cloth to the other; and when all which is upon the table is sufficiently glazed, he draws it over, and exposes a new portion to the same operation. To preserve the cloth at a proper tension, it may be wound smoothly upon a roller or beam, which being set so as to revolve upon its own axis behind the table, another roller to receive the cloth may be placed before, both being secured by a catch, acting in a ratchet wheel. Of late years, however, a great part of the labor employed in glazing cloth has been saved, as the common four or five bowl calender has been altered to fit this purpose by direct pressure.

As a matter of accommodation, the different processes of packing, cording of boxes, sheeting of trunks, and, in general, all the arrangements preparatory to shipments, and also the intimations and surveys necessary for obtaining drawbacks, debentures, or bounties, according to the excise laws, are generally conducted at the calender houses where goods are finished. These operations sufficiently account for the general meaning attached to the word.

CALICO-PRINTING (*Impression d'Indiennes*, Fr.; *Zeugdruckerei*, Germ.) is the art of impressing cotton cloth with topical dyes of more or less permanence. Of late years, silk and woollen fabrics have been made the subjects of a similar style of dyeing. Linens were formerly stained with various colored designs, but since the modern improvements in the manufacture of cotton cloth, they are seldom printed, as they are both dearer, and produce less beautiful work, because flax possesses less affinity than cotton for coloring matters.

This art is of very ancient date in India, and takes its English name from Calicut, a district where it has been practised with great success from time immemorial. The Egyptians, also, appear from Pliny's testimony to have practised at a remote era some of the most refined processes of topical dyeing. "Robes and white veils," says he, "are painted in Egypt in a wonderful way. They are first imbued, not with dyes, but with dye-absorbing drugs, by which, though they seem to be unaltered, yet, when immersed for a little while in a caldron of the boiling dye-liquor, they are found to become painted. Yet, as there is only one color in the caldron, it is marvellous to see many colors imparted to the robe, in consequence of the influence of the excipient drug. Nor can the dye be washed out. A caldron, which would of itself merely confuse the colors of cloths previously dyed, is thus made to impart several pigments from a single dye-stuff, *painting as it boils*." The last expression, *pingitque dum coquit*, is perfectly graphic and descriptive of calico-printing.

The cotton chints counterpanes of great size, called *pallampoors*, which have been manufactured in Madras from the earliest ages, have in like manner peculiar dye-absorbing drugs applied to them with the pencil, as also wax, to protect certain parts of the surface from the action of the dye, and are afterwards immersed in a staining liquor, which, when wax is applied, is usually the cold indigo-vat, but without the wax is a hot liquor similar to the Egyptian. M. Koechlin Roder, of Mulhouse, brought home lately from

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India a rich collection of cloths in this state of preparation, which I saw in the cabinet of the *Société Industrielle* of that interesting emporium of calico-printing. The native implements for applying the wax and coloring bases are placed alongside of the cloths, and form a curious picture of primeval art. There is among other samples an ancient *pallampoor*, five French yards long, and two and a half broad, said to be the labor of Hindoo princesses, which must have taken a lifetime to execute. The printing machinery of great Britain has begun to supersede, for these styles of work, the cheapest hand labor of India.

Calico-printing has been for several hundred years practised by the oriental methods in Asia Minor and the Levant; but it was unknown as an English art till 1696, when a small print-ground was formed upon the banks of the Thames, near Richmond, by a Frenchman—probably a refugee from his own country, in consequence of the revocation of the edict of Nantes. Some time afterwards, a considerable printing work was established at Bromley Hall, in Essex, and several others sprung up successively in Surrey, to supply the London shops with chintses, their import from India having been prohibited by act of parliament in 1700. The silk and woollen weavers, indeed, had all along manifested the keenest hostility to the use of printed calicoes whether brought from the East or made at home. In the year 1680 they mobbed the India House in revenge for some large importations then made of the chintses of Malabar. They next induced the government, by incessant clamors, to exclude altogether the beautiful robes of Calicut from the British market. But the printed goods, imported by the English and Dutch East India companies, found their way into this country, in spite of the excessive penalties annexed to smuggling, and raised a new alarm among the manufacturing population of Spitalfields. The sapient legislators of that day, intimidated, as would appear, by the East London mobs, enacted in 1720 an absurd sumptuary law, prohibiting the *wearing of all printed calicoes whatsoever, either of foreign or domestic origin.* This disgraceful enactment, worthy of the meridian of Cairo or Algiers, proved not only a death-blow to rising industry in this ingenious department of the arts, but prevented the British ladies from attiring themselves in the becoming drapery of Hindostan. After an oppressive operation of ten years, this act was repealed by a partially enlightened set of senators, who were then pleased to permit what they called British calicoes, if made of linen warp, with merely weft of the *hated* cotton, to be printed and worn, upon paying a duty of no less than sixpence the square yard. Under this burden, English calico-printing could not be expected to make a rapid progress. Accordingly, even so lately as the year 1750, no more than 50,000 pieces of mixed stuff were printed in Great Britain, and that chiefly in the neighborhood of London; whereas a single manufacturer, Mr. Coates of Manchester, now-a-days will turn off nearly twenty times that quantity, and there are very many others who manufacture several hundred thousand pieces per annum. It was not till about 1766 that this art migrated into Lancashire, where it has since taken such extraordinary development; but it was only after 1774 that it began to be founded upon right principles, in consequence of the repeal of that part of the act of 1730 which required the warp to be made of linen yarn. Henceforth the printer, though still saddled with a heavy duty of 3*d.* the square yard, was allowed to apply his colors to a homogeneous web, instead of the mixed fabric of linen and cotton substances, which differ in their affinities for dyes.

France pursued for some time a similar false policy with regard to calico-printing, but she emerged sooner from the mists of manufacturing monopoly than England. Her avowed motive was to cherish the manufacture of flax, a native product, instead of that of cotton, a raw material, for which prejudice urged that money had to be exported. Her intelligent statesmen of that day, fully seventy years ago, replied that the money expended in the purchase of cotton was the produce of French industry, beneficially employed, and they therefore took immediate measures to put the cotton fabrics upon a footing of equality. Meanwhile the popular prejudices became irritated to such a degree, by the project of permitting the free manufacture and sale of printed cottons, that every French town possessed of a chamber of commerce made the strongest remonstrances against it. The Rouen deputies declared to the government, "that the intended measure would throw its inhabitants into despair, and make a desert of the surrounding country:" those of Lyons said, "the news had spread terror through all its workshops:" Tours "foresaw a commotion likely to convulse the body of the state:" Amiens said, "that the new law would be the grave of the manufacturing industry of France;" and Paris declared that "her merchants came forward to bathe the throne with their tears upon that inauspicious occasion."

The government persisted in carrying its truly enlightened principles into effect, and with so manifest advantage to the nation, as to warrant the inspector-general of manufactures to make, soon afterwards, the following appeal to those prejudiced bodies:— "Will any of you now deny that the fabrication of printed cottons has occasioned a vast extension of the industry of France, by giving profitable employment to a great many hands in spinning, weaving, bleaching, and printing the colors? Look only at the dyeing department, and say whether it has not done more good to France in a few years than many of your other manufactures have in a century?"

The despair of Rouen has been replaced by the most signal prosperity in the cotton trade, and especially in printed calicoes, for the manufacture of which it possesses 70 different establishments, producing upwards of a million of pieces of greater average size and price than the English. In the district of the Lower Seine, round that town, there are 500 cotton factories of different kinds, which give employment to 118,000 operatives of all orders, and thus procure a comfortable livelihood to probably not less than half a million of people.

The repeal, in 1831, of the consolidated duty of 3½*d.* per square yard upon printed calicoes in Great Britain is one of the most judicious acts of modern legislation. By the improvements in calico-printing, due to the modern discoveries and inventions in chemistry and mechanics, the trade had become so vast as to yield in 1830 a revenue of 2,280,000*l.* levied upon 8,596,000 pieces, of which, however, about three fourths were exported, with a drawback of 1,579,000*l.* 2,281,512 pieces were consumed in that year at home. When the expenses of collection were deducted, only 350,000*l.* found their way into the exchequer, for which pitiful sum thousands of frauds and obstructions were committed against the honest manufacturer. This reduction of duty enables the consumer to get this extensive article of clothing from 50 to 80 per cent. cheaper than before, and thus places a becoming dress within the reach of thousands of handsome females in the humbler ranks of life. Printed goods, which in 1795 were sold for two shillings and three-pence the yard, may be bought at present for eight-pence. In fact, a woman may now purchase the materials of a pretty gown for two shillings. The repeal of the tax has been no less beneficial to the fair dealers, by putting an end to the contraband trade, formerly pursued to an extent equally injurious to them and the revenue. It has, moreover, emancipated a manufacture, eminently dependant upon taste, science, and dexterity, from the venal curiosity of petty excisemen, by whom private improvements, of great value to the inventor, were in perpetual jeopardy of being pirated and sold to any sordid rival. The manufacturer has now become a free agent, a master of his time, his workmen, and his apparatus; and can print at whatever hour he may receive an order; whereas he was formerly obliged to wait the convenience of the excise officer, whose province it was to measure and stamp the cloth before it could be packed,—an operation fraught with no little annoyance and delay. Under the patronage of parliament, it was easy for needy adventurers to buy printed calicoes, because they could raise such a sum by drawbacks upon the export of one lot as would go far to pay for another, and thus carry on a fraudulent system of credit, which sooner or later merged in a disastrous bankruptcy. Meanwhile the goods thus obtained were pushed off to some foreign markets, for which they were possibly not suited, or where they produced, by their forced sales, a depreciation of all similar merchandise, ruinous to the man who meant to pay for his wares.

The principles of calico-printing have been very profoundly studied by many of the French manufacturers, who generally keep a chemist, who has been educated in the Parisian schools of science, constantly at work, making experiments upon colors in a well-mounted laboratory. In that belonging to M. Daniel Kœchlin, of Mulhausen, there are upwards of 3000 labelled vials, filled with chemical reagents, and specimens subservient to dyeing. The great disadvantage under which the French printers labor is the higher price they pay for cotton fabrics above that paid by the English printers. It is this circumstance alone which prevents them from becoming very formidable rivals to us in the markets of the world. M. Barbet, deputy and mayor of Rouen, in his replies to the ministerial commission of inquiry, rates the disadvantage proceeding from that cause at 2 francs per piece, or about 5 per cent. in value. In the annual report of the *Société Industrielle* of Mulhausen, made in December, 1833, the number of pieces printed that year in Alsace is rated at 720,000, to which if we add 1,000,000 for the produce of the department of the Lower Seine, and 280,000 for that of St. Quentin, Lille, and the rest of France, we shall have for the total amount of this manufacture 2,000,000 of pieces, equivalent to nearly 2,400,000 pieces English; for the French piece usually measures 33½ aunes, = 41 yards nearly; and it is also considerably broader than the English pieces upon an average. It is therefore probable that the home consumption of France in printed goods is equal in quantity, and superior in value, to that of England. With regard to the comparative skill of the workmen in the two countries, M. Nicholas Kœchlin, deputy of the Upper Rhine, says, that one of his foremen, who worked for a year in a print-field in Lancashire, found little or no difference between them in that respect. The English wages are considerably higher than the French. The machines for multiplying production, which for some time gave us a decided advantage, are now getting into very general use among our neighbors. In my recent visit to Mulhausen, Rouen, and their environs, I had an opportunity of seeing many printing establishments mounted with all the resources of the most refined mechanisms.

The calico-printing of this country still labors under the burden of considerable taxes upon madder and gallipoli oil, which have counteracted the prosperity of our Turkey red styles of work, and caused them to flourish at Elberfeldt, and some other places on the continent whither a good deal of the English yarns are sent to be dyed, then brough. back, and manufactured into ginghams, checks, &c., or forwarded directly thence to our Russian customers. This fact places our fiscal laws in the same odious light as the facility of pirating printers' patterns with impunity does our chancery laws.

Before cloth can receive good figured impressions its surface must be freed from fibrous down by SINGEING, and be rendered smooth by the CALENDER. See these articles. They are next bleached, with the exception of those destined for Turkey red. See BLEACHING and MADDER. After they are bleached, dried, singed, and calendered, they are lapped round in great lengths of several pieces, stitched endwise together, by means of an apparatus called in Manchester a *candroy*, which bears on its front edge a rounded iron bar, transversely grooved to the right and left from the centre, so as to spread out the web as it is drawn over it by the rotation of the lapping roller. See a figure of this bar subservient to the cylinder printing-machine.

Four different methods are in use for imprinting figures upon calicoes: the first is by small wooden blocks, on whose face the design is cut, which are worked by hand; the second is by larger wood-cut blocks, placed in either two or three planes, standing at right angles to each other, called a Perrotine, from the name of its inventor; the third is by flat copper plates, a method now almost obsolete; and the fourth is by a system of copper cylinders, mounted in a frame of great elegance, but no little complexity, by which two, three, four, or even five colors may be printed on in rapid succession by the mere rotation of the machine driven by the agency of steam or water. The productive powers of this printing automaton are very great, amounting for some styles to a piece in the minute, or a mile of cloth in the hour. The fifth color is commonly communicated by means of what is called a surface cylinder, covered with wooden figures in bass-relief, which, by rotation, are applied to a plane of cloth imbued with the thickened mordants.

The hand blocks are made of sycamore or pear-tree wood, or of deal faced with these woods, and are from two to three inches thick, nine or ten inches long, and five broad, with a strong box handle on the back for seizing them by. The face of the block is either carved in relief into the desired design, like an ordinary wood-cut, or the figure is formed by the insertion edgewise into the wood of narrow slips of flattened copper wire. These tiny fillets, being filed level on the one edge, are cut or bent into the proper shape, and forced into the wood by the taps of a hammer at the traced lines of the configuration. Their upper surfaces are now filed flat, and polished into one horizontal plane, for the sake of equality of impression. As the slips are of equal thickness in their whole depth, from having been made by running the wire through between the steel cylinders of a flatting mill, the lines of the figure, however much they get worn by use, are always equally broad as at first; an advantage which does not belong to wood-cutting. The interstices between the ridges thus formed are filled up with felt-stuff. Sometimes a delicate part of the design is made by the wood-cutter, and the rest by the insertion of copper slips.

The coloring matter, properly thickened, is spread with a flat brush, by a child, upon fine woollen cloth, stretched in a frame over the wax cloth head of a wooden drum or sieve, which floats inverted in a tubful of old paste, to give it elastic buoyancy. The inverted sieve drum should fit the paste tub pretty closely. The printer presses the face of the block on the drum head, so as to take up the requisite quantity of color, applies it to the surface of the calico, extended upon a flat table covered with a blanket, and then strikes the back of the block with a wooden mallet, in order to transfer the impression fully to the cloth. This is a delicate operation, requiring equal dexterity and diligence. To print a piece of cloth 25 yards long, and 30 inches broad, no less than 672 applications of a block, 9 inches long and 5 inches broad, are requisite for each color; so that if there are three colors, or three hands as the French term it, no less than 2016 applications will be necessary. The blocks have pin-points fixed into their corners, by means of which they are adjusted to their positions upon the cloth, so as to join the different parts of the design with precision. Each printer has a color-tub placed within reach of his right hand; and for every different color he must have a separate sieve. Many manufacturers cause their blocks to be made of three layers of wood, two of them being deal with the grain crossed to prevent warping, and the third sycamore for engraving.

The printing shop is an oblong apartment, lighted with numerous windows at each side, and having a solid table opposite to each window. The table B, *fig.* 294, is formed of a strong plank of well-seasoned hard wood, mahogany, or marble, with a surface truly plane. Its length is about 6 feet, its breadth 2 feet, and its thickness 3, 4, or 5 inches. It stands on strong feet, with its top about 36 inches above the floor. At one of its ends there are two brackets C for supporting the axles of the roller E, which carries the white calico to be printed. The hanging rollers E are laid across joists fixed near the roof of the apartment above the printing shop, the ceiling and floor between them being open bar work, at least in the middle of the room. Their use is to facilitate the exposure, and, consequently, the drying of the printed pieces, and to prevent one figure being daubed by another. Should they come to be all filled, the remainder of the goods must be folded lightly upon the stool D.

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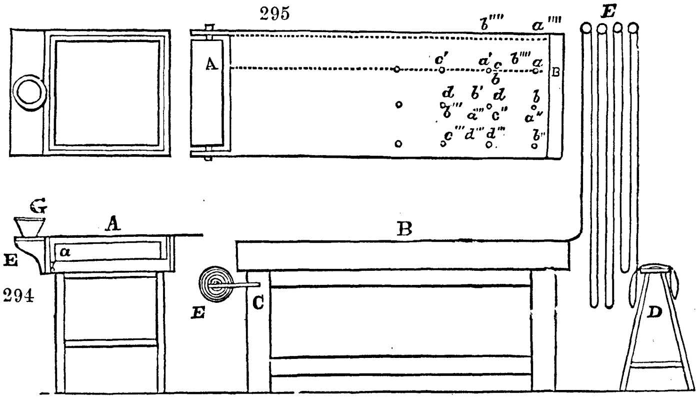


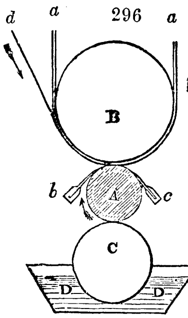
294

The printer stretches a length of the piece upon his table A B, taking care to place the selvage towards himself, and one inch from the edge. He presents the block towards the end, to determine the width of its impression, and marks this line A B, by means of his square and tracing point. The spreader now besmears the cloth with the color, at the commencement, upon both sides of the sieve head; because, if not uniformly applied, the block will take it up unequally. The printer seizes the block in his right hand, and daubs it twice in different directions upon the sieve cloth, then he transfers it to the calico in the line A B, as indicated by the four points *a b c d*, corresponding to the four pins in the corners of the block. Having done so, he takes another daub of the color, and makes the points *a b* fall on *c d*, so as to have at the second stamp *a' b'*, covering *a b* and *c' d'*; and so on, through the rest, as denoted by the accented letters. When one table length is finished, he draws the cloth along, so as to bring a new length in its place.

The grounding-in, or re-entering (*rentrage*), of the other colors is the next process. The blocks used for this purpose are furnished with pin-points, so adjusted that, when they are made to coincide with the pin-points of the former block, the design will be correct; that is to say, the new color will be applied in its due place upon the flower or other figure. The points should not be allowed to touch the white cloth, but should be made to fall upon the stem of a leaf, or some other dark spot. These *rentrages* are of four sorts:—1. One for the mordants, as above; 2. one for topical colors; 3. one for the application of reds; and, 4. one for the application of resist pastes or reserves. These styles have superseded the old practice of pencilling.

The Perrotine is a machine for executing block-printing by mechanical power; and it performs as much work, it is said, as 20 expert hands. I have seen its operation, in many factories in France and Belgium, in a very satisfactory manner; but I have reason to believe that there are none of them as yet in this country. Three wooden blocks, from $2\frac{1}{2}$ to 3 feet long, according to the breadth of the cloth, and from 2 to 5 inches broad, faced with pear-tree wood, engraved in relief, are mounted in a powerful cast-iron frame work, with their planes at right angles to each other, so that each of them may, in succession, be brought to bear upon the face, top, and back of a square prism of iron covered with cloth, and fitted to revolve upon an axis between the said blocks. The calico passes between the prism and the engraved blocks, and receives successive impressions from them as it is successively drawn through by a winding cylinder. The blocks are pressed against the calico through the agency of springs, which imitate the elastic pressure of the workman's hand. Each block receives a coat of colored paste from a woollen surface, smeared after every contact with a mechanical brush. One man, with one or two children for superintending the color-giving surfaces, can turn off about 30 pieces English per day, in three colors, which is the work of fully 20 men and 20 children in block printing by hand. It executes some styles of work to which the cylinder machine, without the surface roller, is inadequate.

The copper-plate printing of calico is almost exactly the same as that used for printing engravings on paper from flat plates, and being nearly superseded by the next machine, need not be described.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The cylinder printing machine consists, as its name imports, of an engraved copper cylinder, so mounted as to revolve against another cylinder lapped in woollen cloth, and imbued with a colored paste, from which it derives the means of communicating colored impressions to pieces of calico passed over it. *Fig.* 296 will give the reader a general idea of this elegant and expeditious plan of printing. The pattern is engraved upon the surface of a hollow cylinder of copper, or sometimes gun metal, and the cylinder is forced by pressure upon a strong iron mandrel, which serves as its turning shaft. To facilitate the transfer of the impression from the engraving to the cotton cloth, the latter is lapped round another large cylinder, rendered elastic by rolls of woollen cloth, and the engraved cylinder presses the calico against this elastic cushion, and thereby prints it as it revolves. Let A be the engraved cylinder mounted upon its mandrel, which receives rotatory motion by wheels on its end, connected with the steam or water power of the factory. B is a large iron drum or roller, turning in bearings of the end frames of the machine. Against that drum the engraved cylinder A is pressed by weights or screws; the weights acting steadily, by levers, upon its brass bearings. Round the drum B the endless web of felt or blanket stuff *a a*, travels in the direction of the arrow, being carried round along with the drum B, which again is turned by the friction of contact with the cylinder A. C represents a clothed wooden roller, partly plunged into the thickened color of the trough D D. That roller is also made to bear, with a moderate force, against A, and thus receives, by friction, in some cases, a movement of rotation. But it is preferable to drive the roller C from the cylinder A, by means of a system of toothed wheels attached to their ends, so that the surface speed of the wooden or paste roller shall be somewhat greater than that of the printing cylinder, whereby the color will be rubbed, as it were, into the engraved parts of the latter.

As the cylinder A is pressed upwards against B, it is obvious that the bearers of the trough and its roller must be attached to the bearings of the cylinder A, in order to preserve its contact with the color-roller C. *b* is a sharp-edged ruler of gun-metal or steel, called the *color doctor*, screwed between two gun-metal stiffening bars; the edge of which wiper is slightly pressed as a tangent upon the engraved roller A. This ruler vibrates with a slow motion from side to side, or right to left, so as to exercise a delicate shaving action upon the engraved surface, as this revolves in the direction of the arrow. *c* is another similar sharp-edged ruler, called the *lint doctor*, whose office it is to remove any fibres which may have come off the calico in the act of printing, and which, if left on the engraved cylinder, would be apt to occupy some of the lines, or at least to prevent the color from filling them all. This *lint doctor* is pressed very slightly upon the cylinder A, and has no transverse motion.

What was stated with regard to the bearers of the color trough D, namely, that they are connected, and moved up and down together with the bearings of the cylinder A, may also be said of the bearers of the two doctors.

The working of this beautiful mechanism may now be easily comprehended. The web of calico, indicated in the figure by the letter *d*, is introduced or carried in along with the blanket stuff *a a*, in the direction of the arrow, and is moved onward by the pressure of the revolving cylinder A, so as to receive the impression of the pattern engraved on that cylinder.

Before proceeding to describe the more complex calico-machine which prints upon cloth 3, 4, or 5 colors at one operation, by the rotation of so many cylinders, I shall explain the modern methods of engraving the cylinder, which I am enabled to do by the courtesy of Mr. Locket, of Manchester, an artist of great ingenuity in this department, who politely allowed me to inspect the admirable apparatus and arrangements of his factory.

To engrave a copper cylinder 3 or 4 inches in diameter, and from 30 to 36 inches long, with the multitude of minute figures which exist in many patterns, would be a very laborious and expensive operation. The happy invention made by Mr. Jacob Perkins, in America, for transferring engravings from one surface to another by means of steel roller dies, was with great judgment applied by Mr. Locket to calico-printing, so long ago as the year 1808, before the first inventor came to Europe with the plan. The pattern is first drawn upon a scale of about 3 inches square, so that this size of figure being repeated a definite number of times, will cover the cylinder. This pattern is next engraved in intaglio upon a roller of softened steel, about 1 inch in diameter, and 3 inches long, so that it will exactly occupy its surface. The engraver aids his eye with a lens, when employed at this delicate work. This roller is hardened by heating it to a cherry-red in an iron case containing pounded bone-ash, and then plunging it into cold water; its surface being protected from oxydizement by a chalky paste. This hardened roller is put into a press of a peculiar construction, where, by a rotatory pressure, it transfers its design to a similar roller in the soft state; and as the former was in intaglio, the latter must be in relievo. This second roller being hardened, and placed in an appropriate volutory press, is employed to engrave by indentation upon the full-sized copper cylinder the whole of its intended pattern. The first roller engraved by hand is called the *die;* the second, obtained from it by a process like that of a milling tool, is called the *mill.* By this indentation and multiplication system, an engraved cylinder may be had for seven pounds, which engraved by hand would cost fifty or upwards. The restoration of a worn-out cylinder becomes extremely easy in this way; the mill being preserved, need merely be properly rolled over the copper surface again.

At other times, the hard roller *die* is placed in the upper bed of a screw press, not unlike that for coining, while the horizontal bed below is made to move upon strong rollers mounted in a rectangular iron frame. In the middle of that bed a smooth cake or flat disc of very soft iron, about 1 inch thick, and 3 or 4 inches in diameter, is made fast by four horizontal adjusting screws, that work in studs of the bed frame. The *die* being now brought down by a powerful screw, worked by toothed wheel-work, and made to press with force upon the iron cake, the bed is moved backwards and forwards, causing the roller to revolve on its axles by friction, and to impart its design to the cake. This iron disc is now case-hardened by being ignited amidst horn shavings in a box, and then suddenly quenched in water, when it becomes itself a die in relievo. This disc die is fixed in the upper part of a screw press with its engraved face downwards, yet so as to be moveable horizontally by traverse screws. Beneath this inverted bed, sustained at its upper surface by friction-rollers, a copper cylinder 30 inches long, or thereby, is mounted horizontally upon a strong iron mandrel, furnished with toothed wheels at one of its ends, to communicate to it a movement upon its axis through any aliquot arcs of the circle. The disc die being now brought down to bear upon the copper cylinder, this is turned round through an arc corresponding in length to the length of the die; and thus, by the steady downward pressure of the screw, combined with the revolution of the cylinder, the transfer of the engraving is made in intaglio. This is, I believe, the most convenient process for engraving, by transfer, the copper of a one-cylinder machine. But when 2, 3, or 4 cylinders are to be engraved with the same pattern for a two, three, or four-colored machine, the die and the mill roller plan of transfer is adopted. In this case, the hardened roller die is mounted in the upper bed of the transfer press, in such a way as to be capable of rotation round its axis, and a similar roller of softened steel is similarly placed in the under bed. The rollers are now made to bear on each other by the action of the upper screw, and while in hard contact, the lower one is caused to revolve, which, carrying round the upper by friction, receives from it the figured impression in relief. When cylinders for a three-colored machine are wanted, three such *mills* are made fac-similes of each other; and the prominent parts of the figure which belong to the other two copper cylinders are filed off in each one respectively. Thus three differently figured *mills* are very readily formed, each adapted to engrave its particular figure upon a distinct copper cylinder.

Some copper cylinders for peculiar styles are not graved by indentation, as just described, but etched by a diamond point, which is moved by mechanism in the most curious variety of configurations, while the cylinder slowly revolves in a horizontal line beneath it. The result is extremely beautiful, but it would require a very elaborate set of drawings to represent the machinery by which Mr. Locket produces it. The copper is covered by a resist varnish while being heated by the transmission of steam through its axis. After being etched, it is suspended horizontally by the ends, for about five minutes, in an oblong trough charged with dilute nitric acid.

With regard to the two and three-colored machines, we must observe, that as the calico in passing between the cylinders is stretched laterally from the central line of the web, the figures engraved upon the cylinders must be proportionally shortened, in their lateral dimensions especially, for the first and second cylinder.

Cylinder printing, though a Scotch invention, has received its wonderful development in England, and does the greatest honor to this country. The economy of labor introduced by these machines is truly marvellous; one of them, under the guidance of a man to regulate the rollers, and the service of a boy, to supply the color troughs, being capable of printing as many pieces as nearly 200 men and boys could do with blocks. The perfection of the engraving is most honorable to our artisans. The French, with all their ingenuity and neat-handedness, can produce nothing approaching in excellence to the engraved cylinders of Manchester,—a painful admission, universally made to me by every eminent manufacturer in Alsace, whom I visited in my late tour.

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Another modification of cylinder printing, is that with wooden rollers cut in relief; it is called *surface printing*, probably because the thickened color is applied to a tense surface of woollen cloth, from which the roller takes it up by revolving in contact with the cloth. When the copper cylinders and the wooden ones are combined in one apparatus, it has got the appropriate name of the *union* printing machine.

In mounting three or more cylinders in one frame, many more adjustments become necessary than those described above. The first and most important is that which ensures the correspondence between the parts of the figures in the successive printing rollers, for unless those of the second and subsequent engraved cylinders be accurately inserted into their respective places, a confused pattern would be produced upon the cloth as it advances round the pressure cylinder B, *figs.* 296, 297.

Each cylinder must have a forward adjustment in the direction of rotation round its axis, so as to bring the patterns into correspondence with each other in the length of the piece; and also a lateral or traverse adjustment in the line of its axis, to effect the correspondence of the figures across the piece; and thus, by both together, each cylinder may be made to work symmetrically with its fellows.

Fig. 297 is a cross section of a four-color cylinder machine, by which the working parts are clearly illustrated.

A A A is a part of the two strong iron frames or cheeks, in which the various rollers are mounted. They are bound together by the rods and bolts *a a a a*.

B is the large iron pressure cylinder, which rests with its gudgeons in bearings or bushes, which can be shifted up and down in slots of the side cheeks A A. These bushes are suspended from powerful screws *b*, which turn in brass nuts, made fast to the top of the frame A, as is plainly shown in the figure. These screws serve to counteract the strong pressure applied beneath that cylinder, by the engraved cylinders D E.

C D E F are the four printing cylinders, named in the order of their operation. They consist of strong tubes of copper or gun-metal, forcibly thrust by a screw press upon the iron mandrels, round which as shafts they revolve.

The first and last cylinder C and F are mounted in brass bearings, which may be shifted in horizontal slots of the frame A. The pressure roller B, against whose surface they bear with a very little obliquity downwards, may be nicely adjusted to that pressure by its elevating and depressing screws. By this means C and F can be adjusted to B with geometrical precision, and made to press it in truly opposite directions.

The bearings of the cylinders D and E are lodged also in slots of the frame A, which point obliquely upwards, towards the centre of B. The pressure of these two print cylinders C and F is produced by two screws *c* and *d*, which work in brass nuts, made fast to the frame and very visible in the figure. The frame-work in which these bearings and screws are placed, has a curvilinear form, in order to permit the cylinders to be readily removed and replaced; and also to introduce a certain degree of elasticity. Hence the pressure applied to the cylinders C and F, partakes of the nature of a spring; a circumstance essential to their working smoothly, on account of the occasional inequalities in the thickness of the felt web and the calico.

The pressure upon the other two print cylinders D and E is produced by weights acting with levers against the bearings. The bearings of D are, at each of their ends, acted upon by cylindrical rods, which slide in long tubular bosses of the frame, and press with their nuts *g* at their under end upon the small arms of two strong levers G, which lie on each side of the machine, and whose fulcrum is at *h* (in the lower corner at the left hand). The long arms of these levers G, are loaded with weights H, whereby they are made to press up against the bearings of the roller D, with any degree of force, by screwing up the nut *g*, and hanging on the requisite weights.

The manner in which the cylinder E is pressed up against B, is by a similar construction to that just described. With each of its bearings, there is connected by the link *k*, a curved lever I, whose fulcrum or centre of motion is at the bolt *l*. To the outer end of this lever, a screw, *m*, is attached, which presses downwards upon the link *n*, connected with the small arm of the strong lever *k*, whose centre of motion is at *o*. By turning therefore the screw *m*, the weight L, laid upon the end of the long arm of the lever K (of which there is one upon each side of the machine), may be made to act or not at pleasure upon the bearings of the cylinder E.

In tracing the operation of this exquisite printing machine, we shall begin with the first engraved cylinder C. Its bearings or bushes shift, as was already stated, in slots of the frame A. Each of them consists of a round piece of iron, to which the end of the screw *c* is joined, in the same way as at *d*, in the opposite side. In each of these iron bearings, a concave brass is inserted to support the collar of the shaft, and in a dovetailed slit of this brass, a sliding piece is fitted, upon which a set or adjusting screw in the iron bearing acts, and which, being forced against the copper cylinder C, serves to adjust the line of its axis, and to keep it steady between its bearings, and true in its rotatory motion. Upon the iron bearing a plate is screwed, provided with two flanges,

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which support the color trough *q*, and the color roller M. This trough, as well as the others to be mentioned presently, is made of sheet copper in the sides and bottom, and fixed upon a board; but its ends are made of plates of cast copper or gun-metal to serve as bearings to the color roller M. The trough and its roller may be shifted both together into contact with the printing cylinder C, by means of the screw *r*. Near *s*, seen above the roller, C, and *t* below it, are sections of the two doctors, which keep the engraved cylinders in sound working condition; the former being the colour doctor, and the latter the lint doctor. Their ends lie in brasses, which may be adjusted by the screws *u* and v, working in the respective brackets, which carry their brasses, and are made fast to the iron bearings of the cylinder.

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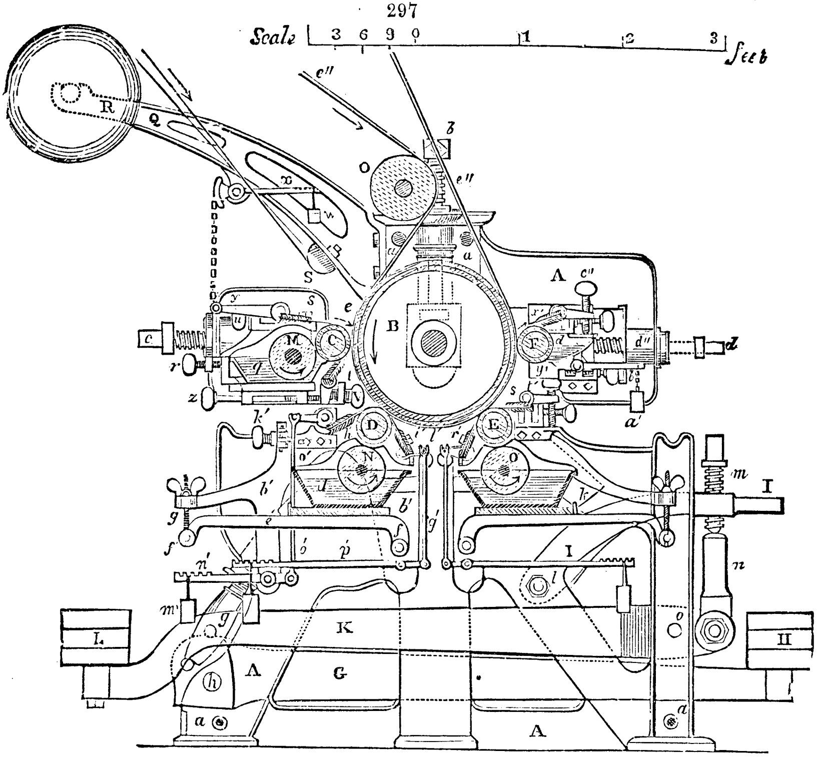


The pressure of the color doctor is produced by two weights *w*, (see high up on the frame work,) which act on a pair of small levers *x*, (one on each side of the machine,) and thus, by means of the chains, tend to lift the arms *y*, attached to the end axles of the doctor. The pressure of the lint doctor upon the cylinder C, is performed by the screw *z*, pressing upon an arm which projects downwards, and is attached to the axle of that doctor.

The bearings of the second printing cylinder D, consist at each end of a mass of iron (removed in the drawing to show the mechanism below it), which shifts in the slanting slot of the frame A. In each of these masses there is another piece of iron, which slides in the transverse direction, and may be shifted by the adjusting screw *a′* fixed to it, and working in a nut cast upon the principal bearing above described. To the inner bearings, which carry the brasses in which the shaft lies, are screwed the two curved arms *b′ b′* to which are attached the bearings &c., for the color trough and the doctors. In these brasses there are also dovetailed pieces, which slide and are pressed by set screws furnished with square heads in the iron secondary bearings, which serve, as before said, to adjust the printing cylinder in the line of its axis, while other screws adjust the distance of the cloth upon which the second color is printed, and the line of contact with the cylinder B.

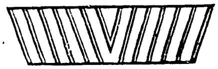
N, is the color roller of D, and *d′* the color trough, which rests by its board upon the lever *e′*; whose centres of motion *f′*, are made fast to the curved arms *b′*, fixed at the bearings of the cylinder, and whose ends are suspended by screws g'; whereby the color roller N, may be pressed with greater or less force to the cylinder D. h' and i' are the two doctors of this cylinder; the former being the color, the latter the lint doctor They rest, as was said of the cylinder C, in brasses which are adjustable by means of screws, that work in the studs or brackets by which the brasses are supported. These brackets must of course be screwed to the secondary bearing-pieces, in order that they may keep their position, into whatever direction the bearings may be shifted. k' and l' are these set screws for the color and lint doctors. The pressure of the former upon the cylinder D, is produced by weights m', acting upon levers n', and pressing by rods or links o', upon arms attached to each end of the axis of the doctor. (See the left hand side of the figure near the bottom.) The lint-doctor i' is pressed in a similar way at the other side upon the cylinder D, by the weights acting upon levers p', and by rods q' upon arms fixed at each end of the axis of the doctor.

The bearings of the third printing cylinder E, are of exactly the same construction as that above described, and therefore require no particular detail. The lint doctor s, is here pressed upon the engraved cylinder by screws t', working in the ends of studs or arms fixed upon each end of the axis of the doctor, and pressing upon flanges cast upon the brackets in which the brasses of the doctor's axis lie, which are made fast to the bearings of the cylinder E.

The bearings of the fourth copper cylinder F, are also constructed in a similar way, Each consists of a first bearing, to which is joined the end of the screw d, by which it is made to slide in a slot of the frame. Another bearing, which contains the brass for the shaft of the cylinder, can be shifted up and down in a transverse direction by a screw z', of the second bearing, working in a nut cast upon the first bearing. To this secondary bearing, plates are made fast by the screws v' v' to the inside, to carry the studs or brackets of the doctors x' and y'. In the brasses of the cylinder shaft, dovetailed pieces are made to slide, being pressed by set screws w', against the engraved cylinder F, similar to what has been described for adjusting the cylinders to one another. This cylinder has no separate color roller, nor trough, properly speaking, but the color doctor y' is made concave to serve the purpose of a trough in supplying the engraved lines of the cylinder with color. With this view the top plate of the doctor is curved to contain the colored paste, and it is shut up at the ends by pieces of wood made to fit the curvature of the doctor. Its pressure against the engraved surface is produced by weights a'', acting at the ends of arms b'', attached to the ends of the axis of the doctor. The pressure of the lint doctor x' is given by screws c'', working in arms attached to the ends of the axis of the doctor, and pressing upon the flanges d'', cast upon the brackets which carry the brasses for the axis of the doctor. These brasses are themselves adjustable, like those of all the other cylinders, by set screws in the brackets, which work in the nuts formed in the brasses.

e'' e'', is the endless web of felt stuff which goes round the cylinder B, and constitutes the soft elastic surface upon which the printing cylinders C, D, E, and F exercise their pressure. This endless felt is passed over a set of rollers at a certain distance from the machine, to give opportunity for the drying up of any coloring paste which it may have imbibed from the calico in the course of the impressions. In its return to the machine in the direction of the arrow, it is led over a guide roller O, which is thereby made to revolve. Upon the two ends of this, and outside of the bearings which are fixed upon the tops of the frame A, are two eccentrics, one of which serves to give a vibratory traverse movement to the color doctors s', h', and r' of the three cylinders, C, D, and E, whilst the other causes the color doctor y' of the cylinder F, to make lateral vibrations.

Q is one of a pair of cast-iron brackets, screwed on at the back of the side-frames or cheeks A A, to carry the roller filled with white calico R, ready for the printing operations. Upon the end of the shaft whereon the calico is coiled, a pulley is fixed, over which a rope passes suspending a weight in order to produce friction, and thereby resistance to the action which tends to unwind the calico. In winding it upon that and similar rollers, the calico is smoothed and expanded in breadth by being passed over one or more grooved rods, or over a wooden bar S, *fig.* 298, the surface of which is covered with wire, so as to have the appearance of a united right and left-handed screw. By this device, the calico, folded or creased at any part, is stretched laterally from the centre, and made level. It then passes over the guide-roller O, where it comes upon the surface of the felt e'' e'', and thence proceeds under its guidance to the series of printing cylinders.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Three and four-color machines, similar to the above, are now at work in many establishments in Lancashire, which will turn off a piece of 28 yards per minute, each of the three or four cylinders applying its peculiar part of the pattern to the cloth as it passes along, by ceaseless rotation of the unwearied wheels. At this rate, the astonishing length of one mile of many-colored web is printed with elegant flowers and other figures in an hour. When we call to mind how much knowledge and skill are involved in this process, we may fairly consider it as the greatest achievement of chemical and mechanical science.

Before entering upon the different styles of work which constitute calico-printing, I shall treat, in the first place, of what is common to them all, namely, the thickening of the mordants and colors. This is an operation of the greatest importance towards the successful practice of the art. Several circumstances may require the consistence of the thickening to be varied; such as the nature of the mordant, its density, and its acidity. A strong acid mordant cannot be easily thickened with starch; but it may be by roasted starch, vulgarly called British gum, and by gum arabic or senegal. Some mordants which seem sufficiently inspissated with starch, liquefy in the course of a few days, and, being apt to run in the printing-on, make blotted work. In France, this evil is readily obviated by adding one ounce of spirits of wine to half a gallon of color—a remedy which the English excise duties render too costly.

The very same mordant, when inspissated to different degrees, produces different tints in the dye-copper—a difference due to the increased bulk from the thickening substance; thus, the same mordant, thickened with starch, furnishes a darker shade than when thickened with gum. Yet there are circumstances in which the latter is preferred, because it communicates more transparency to the dyes, and because, in spite of the washing, more or less of the starch always sticks to the mordant. The gum has the inconvenience, however, of drying too speedily, and of also increasing too much the volume of the mordants; by both of which causes it obstructs their combination with the stuff, and the tints become thin or scratchy.

The substances generally employed as thickeners are the following:—

1. Wheat starch.
2. Flour.
3. Roasted starch.
4. Gum senegal.
5. Gum tragacanth.
6. Salep.
7. Pipe-clay, mixed with gum senegal.
8. Sulphate of lead.
9. Sugar.
10. Molasses.
11. Glue.

After thickening with gum, we ought to avoid adding metallic solutions in the liquid state; such as nitrate of iron, of copper, solutions of tin, of subacetate of lead, &c.; as they possess the property of coagulating gum. I shall take care to specify the nature and proportion of thickening to be employed for each color; a most important matter, hitherto neglected by English writers upon calico-printing.

The atmosphere of the printing shops should never be allowed to cool under 65° or 70° F.; and it should be heated by proper stoves in cold weather, but not rendered too dry. The temperature and moisture should therefore both be regulated with the aid of thermometers and hydrometers, as they exercise a great influence upon all the printing processes, and especially upon the combination of the mordant with the cloth. In the course of the desiccation, a portion of the acetic acid evaporates with the water, and subacetates are formed, which combine with the stuff in proportion as the solvent principle escapes; the water, as it evaporates, carries off acetic acid with it, and thereby aids the fixation of bases. These remarks are peculiarly appropriate to delicate impressions by the cylinder machine, where the printing and drying are both rapidly effected. In the lapis lazuli style, the strong mordants are apt to produce patches, being thickened with pipe-clay and gum, which obstruct the evaporation of the acids. They are therefore apt to remain, and to dissolve a portion of the mordants at their immersion in the blue vat, or at any rate in the dung bath. In such a case, a hot and humid air is indispensable, after the application of the mordants, and sometimes the stuffs so impregnated must be suspended in a damp chamber. To prevent the resist pastes becoming rapidly crusty, substances apparently useless are mixed with them, but which act beneficially by their hygrometric qualities, in retarding the desiccation. Oil also is sometimes added with that view.

It is often observed that goods printed upon the same day, and with the same mordant, exhibit inequalities in their tints. Sometimes the color is strong and decided in one part of the piece, while it is dull and meager in another. The latter has been printed in too dry an atmosphere. In such circumstances a neutral mordant answers best, especially if the goods be dried in a hot flue, through which humid vapors are in constant circulation.

In padding, where the whole surface of the calico is imbued with mordant, the drying apartment or flue, in which a great many pieces are exposed at once, should be so constructed as to afford a ready outlet to the aqueous and acid exhalations. The cloth ought to be introduced into it in a distended state; because the acetic acid may accumulate in the foldings, and dissolve out the earthy or metallic base of the mordant, causing white and gray spots in such parts of the printed goods. Fans may be employed with great advantage, combined with Hot Flues. (See this article.)

In the color laboratory, all the decoctions requisite for the print work should be ready prepared. They are best made by a steam heat, by means of copper boilers of a cylindric form, rounded at the bottom, and incased within a cast-iron cylinder, the steam being supplied to the space between the two vessels, and the dye-stuff and water being introduced into the interior one, which for some delicate purposes may be made of tin, or copper tinned inside. A range of such steam apparatus should be placed either along one of the side walls, or in the middle line of the laboratory. Proper tables, drawers, vials, with chemical reagents, measures, balances, &c., should also be provided. The most useful dye-extracts are the following:—

Decoction of logwood, of Brazil-wood, of Persian berries, of quercitron bark, of nutgalls, of old fustic, of archil or cutbear, of cochineal, of cochineal with ammonia, of catechu.

The following mordants should also be kept ready prepared:—

1. Aluminous mordant.

Take 50 gallons of boiling water.
100 lbs. of alum.
10 lbs. of soda crystals.
75 lbs. of acetate of lead.

The soda should be added slowly to the solution of the alum in the water, and when the effervescence is finished, the pulverized acetate of lead is put in and well stirred about till it be all dissolved and decomposed. During the cooling, the mixture should be raked up a few times, and then allowed to settle. The supernatant liquor is the mordant; it has a density of 11° or 11½° Baumé. It serves for reds and pinks, and enters into the composition of puce and lilach.

2. Aluminous mordant.

Take 50 gallons of water.
100 lbs. of alum.
10 lbs. of soda crystals.
100 lbs. of acetate of lead;—operate as above directed.

The supernatant liquor here has a density of 12° Baumé; it is employed for lapis resists or reserves, and the cylinder printing of madder reds.

3. Aluminous mordant.

Take 50 gallons of water.
100 lbs of alum.
6 lbs. of soda crystals.
50 lbs. of acetate of lead;—operate as above directed.

This mordant is employed for uniform yellow grounds.

4. Aluminous mordant.

This is made by adding potash to a solution of alum, till its earth begins to be separated, then boiling the mixture to precipitate the subsulphate of alumina, which is to be strained upon a filter, and dissolved in acetic acid of moderate strength with the aid of heat. This mordant is very rich in alumina, and marks 20° B.

5. Aluminous mordant.

Take 12½ gallons of water.
100 lbs. of alum.
150 lbs. of liquid pyrolignite of lime at 11½° Baumé.

This mordant is made with heat like the first; after cooling, some alum crystallizes, and it marks only 12½° B.

A mordant is made by solution of alum in potash, commonly called—

6. Aluminate of potash. The caustic ley is prepared by boiling together for an hour 100 gallons of water, 200 lbs. of potash, and 80 lbs. of quicklime; the mixture is then allowed to settle, the supernatant liquor is decanted, and evaporated till its density be 35° B. In 30 gallons of that ley at a boiling heat, 100 lbs. of ground alum are to be dissolved. On cooling, crystals of sulphate of potash separate. The clear liquor is to be decanted off, and the crystals being washed with a little water, this is to be added to the ley. About 33 gallons of mordant should be obtained.

Mordant for Black.

The pyrolignite of iron, called iron liquor in this country, is the only mordant used in calico-printing for black, violet, puce, and brown colors. The acetate of alumina, prepared from pyroligneous acid, is much used by the calico-printers under the name of red or yellow liquor, being employed for these dyes.

We may observe that a strong mordant, like No. 2, does not keep so well as one of mean density, such as No. 1. Too much mordant relatively to the demands of the works should therefore not be made at a time.

There are eight different styles of calico-printing, each requiring different methods of manipulation, and peculiar processes.

1. The madder style, to which the best chintzes belong, in which the mordants are applied to the white cloth with many precautions, and the colors are afterwards brought up in the dye-bath. These constitute permanent prints.

2. The padding or *plaquage* style, in which the whole surface of the calico is imbued with a mordant, upon which afterwards different colored figures may be raised, by the topical application of other mordants joined to the action of the dye-bath.

3. The reserve style, where the white cloth is impressed with figures in resist paste, and is afterward subjected first to a cold dye, as the indigo vat, and then to a hot dye-bath, with the effect of producing white or colored spots upon a blue ground.

4. The discharge or *rongeant* style, in which thickened acidulous matter, either pure or mixed with mordants, is imprinted in certain points upon the cloth, which is afterwards padded with a dark-colored mordant, and then dyed, with the effect of showing bright figures on a darkish ground.

5. China blues; a style resembling blue stone-ware, which requires very peculiar treatment.

6. The decoloring or *enlevage* style; by the topical application of chlorine or chromic acid to dyed goods. This is sometimes called a discharge.

7. Steam colors; a style in which a mixture of dye extracts and mordants is topically applied to calico, while the chemical reaction which fixes the colors to the fibre is produced by steam.

8. Spirit colors; produced by a mixture of dye extracts, and solution of tin, vulgarly called spirit by dyers. These colors are brilliant but fugitive.

I. The madder style; called by some dip colors. The true chints patterns belong to it; they have from 5 to 7 colors, several of which are grounded-in after the first dye has been given in the madder bath.

In dyeing with madder, sumach, fustic, or quercitron, is sometimes added to the bath, in order to produce a variety of tints with the various mordants at one operation.

1. Suppose we wish to produce flowers or figures of any kind containing red, purple, and black colors, we may apply the three mordants at once, by the three-color cylinder machine, putting into the first trough acetate of alumina thickened; into the second, acetate of iron; and into the third, a mixture of the two; then drying in the air for a few days to fix the iron, dunging and dyeing up in a bath of madder and sumach. If we wish to procure the finest madder reds and pinks, besides the purple and black, we must apply at first only the acetate of alumina of two densities, by two cylinders, dry, dung, and dye up, in a madder bath. The mordants of iron liquor for the black, and of iron liquor mixed with the aluminous for purple, must be now grounded-in by blocks, taking care to insert these mordants into their precise spots: the goods being then dried with airing for several days, and next dunged, are dyed up in a bath of madder and sumach. They must be afterwards cleared by branning. See BRAN, DUNGING, and MADDER.

2. Suppose we wish to produce yellow with red, pink, purple, and black; in this case the second dye-bath should contain quercitron or fustic, and the spots intended to be yellow should receive the acetate of alumina mordant.

3. The mordant for a full red may be acetate of alumina, of spec. grav. 1·055, thickened with starch, and tinged with Brazil-wood; that for a pale red or pink, the same at spec. gravity 1·014, thickened with gum; that for a middling red, the same at spec. gravity 1·027, thickened with British gum; and for distinction's sake, it may be tinged yellow with Persian berries. The mordant for black is a pyroligneous acetate of iron, of specific gravity 1·04; for purple the same, diluted with six times its volume of water; for chocolate, that iron liquor mixed with acetate of alumina, in various proportions according to the shade wanted. Sumach is mixed with the madder for all these colors except for the purple. The quantity of madder required varies according to the body of color to be put upon the cloth, being from one pound per piece to three or even four. The goods must be entered when the copper is cool, be gradually heated during two or three hours, up to ebullition, and sometimes boiled for a quarter of an hour; the pieces being all the while turned with a wince from the one side of the copper to the other. (See WINCE.) They are then washed and boiled in bran and water for ten or fifteen minutes. When there is much white ground in the chints, they must be branned a second or even a third time, with alternate washing in the dash-wheel To complete the purification of the white, they are spread upon the grass for a few days; or what is more expeditious, and equally good if delicately managed, they are winced for a few minutes in a weak solution of chloride of lime.

4. In the grounding-in for yellow, after madder reds, the aluminous mordant being

applied, &c., the piece is dyed, for about an hour, with one pound of quercitron bark, the infusion being gradually heated to 150° or 160°, but not higher.

5. A yellow is sometimes applied in chints work after the other colors are dyed, by means of a decoction of Persian berries mixed with the aluminous mordant, thickened with flour or gum, and printed-on with the block; the piece, when dry, is passed through a weak carbonated alkaline water, or lime water, then washed and dried for the market.

6. *Black mordant.*—Take half a gallon of acetate of iron, of spec. grav. 1·04, 4 ounces of starch, and 4 ounces of flour. The starch must first be moistened with the acetate, then the flour must be added, the rest of the acetate well mixed with both, and the whole made to boil over a brisk fire for five minutes, stirring meanwhile to prevent adhesion to the bottom of the pot. The color must be poured into an earthen pipkin, and well mixed with half an ounce of gallipoli oil. In general, all the mordants, thickened with starch and flour, must be boiled for a few minutes. With British gum or common gum, they must be heated to 160° F., or thereby, for the purpose merely of dissolving them. The latter should be passed through a sieve to separate the impurities often present in common gum.

7. *Puce mordant.*—Take a quart of acetate of alumina and acetate of iron, each of spec. grav. 1·04, mixed and thickened like the black, No. 6. To give the puce a reddish tinge, the acetate of alumina should have a specific gravity of 1·048, and the iron liquor only 1·007.

Red mordants are thickened with British gum, and are sufficiently colored with the addition of any tinging decoction.

8. *Violet mordants.*—These consist either of a very weak solution of acetate of iron, of specific gravity 1·007, for example; or of a little of the stronger acetate of 1·04, mixed with acetate of alumina, and a little acetate of copper, thickened with starch or British gum. The shades may be indefinitely varied by varying the proportions of the acetates.

When black is one of the colors wanted, its mordant is very commonly printed-on first, and the goods are then hung upon poles in the drying-room, where they are aired for a few days, in order to fix the iron by its peroxydizement; the mordants for red, violet, &c., are then grounded in, and the pieces are dyed up, after dunging and washing, in the madder bath, into which, for certain shades, sumach, galls, or fustic is added. The goods are brightened with a boil in soap water; occasionally also in a bath, containing a small quantity of solution of tin or common salt. The following mode of brightening is much extolled by the French, who are famous for their reds and roses.

1. A soap boil of forty minutes, at the rate of 1 pound for every 2 pieces. Rinse in clear water.

2. Pass through chloride of soda solution of such strength that two parts of it decolor one part of Gay Lussac's test liquor. See Chloride of Lime and Indigo. Wince the pieces through it for 40 minutes. Rinse again.

3. Pass it again through the soap bath, No. 1.

4. Brighten it in a large bath of boiling water, containing 4 pounds of soap, and 1 pound of a cream-consistenced salt of tin, containing nearly half its weight of the muriate of tin, combined with as much nitric acid of spec. grav. 1·288. This strong nitro-muriate having been diluted with a little water, is to be slowly poured into the bath of soap water, and well mixed by stirring. The pieces are now put in, and winced through it for one half or three quarters of an hour.

5. Repeat the soap boil, No. 1. Rinse and dry.

9. *Grounding-in of Indigo blue.*

Take half a gallon of water of 120° F., 8 ounces of ground indigo, and 8 ounces of red sulphuret of arsenic (orpiment), 8 ounces of quicklime, mix together, and heat the mixture to the boiling point; withdraw from the fire, and add, when it is lukewarm, 6 ounces of carbonate of soda, stir and leave the whole at rest till the next day. Then decant the clear liquor, and thicken every quart of it with half a pound of gum. This color ought to be green, and be preserved in a close vessel. When used, it is put into a pot with a narrow orifice, the pencil is dipped into it, wiped on the edge of the pot, and immediately applied by hand. This plan is tedious, and is nearly superseded by the following grounding blue.

Take half a gallon of caustic soda ley of spec. grav. 1·15, heated to 120° F.

12 ounces of hydrate of protoxyde of tin, obtained by precipitating it from the muriate of tin by solution of potash.

8 ounces of ground indigo; heat these mixed ingredients to the boiling point, then move the pot off and on the fire two or three times in succession, and finally thicken with 3 pounds of raw sugar. In order to apply this by the block, the following apparatus is employed, called the *canvass frame; figs.* 299, 300. It is formed of a copper

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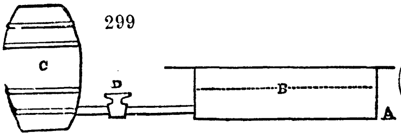
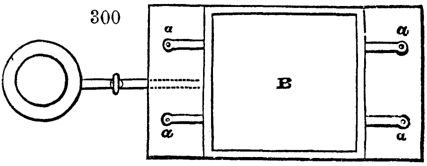


300



case or box A, in which is laid a frame B, filled with pretty stout canvass The box communicates by a tube with the cistern C, mounted with a stop-cock D. *Fig.* 300 represents the apparatus in plan: A, the box; B, the canvass, with its edges *a a a a*, fixed by pin points to the sides. The color is *teared* (*tiré*), or spread even, with a wooden scraper as broad as the canvass. In working with this apparatus, the color being contained in the vessel C is drawn off into the case A, by opening the stop-cock D, till it rises to the level of the canvass. The instant before the printer daubs the block upon the canvass, the *tearer* (*tireur*), boy or girl, runs the scraper across it to renew its surface; and the printer immediately transfers the color to the cloth. In this kind of printing great skill is required to give evenly impressions. As the blue is usually applied to somewhat large designs, it is very apt to run; an inconvenience counteracted by dusting fine dry sand upon the cloth as soon as it is blocked. The goods must be washed within 24 hours after being printed.

10. *Topical grounding blue for the cylinder press.*

Take 3½ gallons of caustic soda ley of spec. grav. 1·1
 3½ lbs. of ground indigo.
 5 lbs. of precipitated protoxyde of tin (as above).

Boil the mixed ingredients for ten minutes, take them from the fire, and add, first, 3 lbs. of Venice turpentine; then 11 lbs. of gum.

Put this mixture into the color trough, print with it, and after two days wash in the dash-wheel; then pass it through a soap-bath, along with a little soda, to brighten the blue, and to take off its grayish tint.

The use of the turpentine is easily explained; it serves to exclude the atmospherical oxygen, and prevent the regeneration of the indigo blue, before it is spread upon the cloth.

After the application to white calico of a similar blue, into which a little acid muriate of tin has been put, the goods are dipped for ten minutes in thin milk of lime, shaking the frame all the time. They are then washed, and cleared with a soap boil. The following color remains long in the deoxydized state from its containing 8 ounces of indigo, 10 ounces of hydrated protoxyde of tin, and 1½ pounds of solution of muriate of tin, to 2 quarts of soda ley of 1·15, thickened with 2½ pounds of gum. This blue may be applied by either the block or the cylinder.

11. Topical Prussian blue for grounding.

2 quarts of water with 8 ounces of starch are to be mixed and boiled; add 2¼ ounces of a liquid Prussian blue color, prepared by triturating three quarters of an ounce of that pigment with as much muriatic acid, leaving the ingredients to react upon each other for 24 hours, and then adding three quarters of an ounce of water.

Add 4 ounces of liquid perchloride of tin (oxymuriate).

Mix all together, and pass through a searce. This color is not very fast; cloth printed with it will bear only rinsing.

12. Prussian blue figures are impressed as follows:—

Dissolve 8 ounces of sulphate of iron, and as much acetate of lead, separately in 2 quarts of boiling water; mix well, and settle. Take one quart of this clear liquor reduced to spec. grav. 1·02, one quart of mucilage containing 3 pounds of gum, colored with a little prussiate of potash, mix into a mordant, and print it on with the cylinder. Two days afterwards wash in tepid water containing a little chalk, and then pass the cloth through a solution of prussiate of potash in water, sharpened with a little muriatic acid, till it takes the desired hue. Finally rinse.

II. The padding or *plaquage* style, called *foulard* also by the French. See PADDING.

Any mordant whatever, such as the acetates of alumina, or of iron, or their mixture, may be applied to the piece by the padding machine, after which it is dried in the HOT FLUE, washed, dunged, dyed, washed, and brightened.

Colors from metallic oxydes are very elegantly applied by the padding process. Thus the iron buff, the manganese bronze, and the chrome yellows and greens are given.

1. Iron buff or chamois.

Take 50 gallons of boiling water;
 150 pounds of sulphate of iron; dissolve along with
 10 pounds of alum; which partly saturate by the gradual addition of
 5 pounds of crystals of soda; and in this mixture dissolve

50 pounds of pyroligneous acetate of lead. Allow the whole to settle, and draw off the clear supernatant liquid.

For furniture prints this bath should have the spec. grav. 1·07.

The calico being padded in it, is to be dried in the hot-flue; and after 48 hours suspension is to be washed in water at 170° containing some chalk, by the wince apparatus. It is then washed, by the same apparatus, in hot water, containing a pailful of soda ley of spec. grav. 1·04.

For light tints the padding liquor should be reduced to the spec. grav. 1·01. The dye in either case may be brightened by wincing through a weak solution of chloride of lime.

Nitrate of iron diffused through a body of water may be also used for padding, with alternate washings in water, and a final wincing in a weak alkaline ley.

With a stronger solution, similar to the first, the boot-top color is given.

2. The bronze or *solitaire.*

The goods are to be padded in a solution of the sulphate or muriate of manganese, of a strength proportional to the shade desired, dried in the hot-flue, and then raised by wincing them in a boiling-hot caustic ley, of spec. grav. 1·08, and next through a weak solution of chloride of lime, or soda. They are afterwards rinsed. Instead of passing them through the chloride, they may be merely exposed to the air till the manganese attracts oxygen, then rinsed and dried.

When the manganese solution has the density of 1·027, it gives a light shade; at the density of 1·06, a shade of moderate depth, and at 1·12 a dark tint.

The texture of the stuff is apt to be injured during the oxydation of the manganese.

3. *Carmelite* is obtained by padding in a mixture of muriate or sulphate of manganese and acetate of iron, then proceeding as above.

4. *Copper green* is given by padding in a mixed solution of sulphate and acetate of copper with a little glue, drying in the hot-flue, and next day padding in a caustic ley of spec. grav. 1·05. The goods are then rinsed, and padded through a solution made with 8 ounces of arsenious acid combined with 4 ounces of potash diluted with 2 gallons of water. They are finally rinsed and dried.

5. Olive and cinnamon colors are given by padding through mixed solutions of the acetate of iron and sulphate of copper; drying, and padding in a caustic ley of spec grav. 1·05.

6. *Green and solitaire* form a pleasing umber, or hellebore shade, which may be obtained by padding through a mixed solution of manganese and aceto-sulphate of copper, and raising the shades as above prescribed.

7. *Chrome yellow.*

Pad in a solution of bichromate of potash containing 8 ounces of it to the gallon of water; then dry with moderate heat, and pad in a solution of acetate or nitrate of lead, containing 6 or 8 ounces in the gallon of water; wash, and dry. Or we may pad first in a solution of acetate of lead containing a little glue; dry, and pad in solution of bichromate of potash. Then rinse. The last process is apt to occasion cloudiness. To obtain a light lemon tint, we must pad in a solution of acetate of lead of double the above strength, or 16 ounces to the gallon, then wince the pieces through weak milk of lime, rinse, pad through bichromate of potash, rinse and dry.

8. *Chrome orange.*

Pad through a mixed solution of the subacetate and acetate of lead, three times in succession, and dry in the hot-flue; then wince for ten minutes through weak milk of lime; rinse; wince for a quarter of an hour in a warm solution of bichromate of potash; and finally raise the color by wincing the goods through hot lime-water.

9. *Prussian blue.*

Pad in the preceding chamois liquor of the spec. grav. 1·007; dry in the hot-flue; wince well in chalky water at 160° F., and then dye by wincing in the following liquor:—

Dissolve 5 ounces of prussiate of potash, in 25 gallons of water heated to 90° or 100°, adding 2 ounces of sulphuric acid; afterwards rinse, and brighten in a very dilute sulphuric acid.

10. *Green* is given by padding goods, previously dyed in the indigo vat, in a solution of acetate of lead containing a little glue; and then padding them in a warm solution of bichromate of potash; finally rinsing and drying.

III. Resist pastes or reserves; these are subservient to the cold indigo vat, and they may be distributed under four heads; 1. fat reserves; 2. reserves with bases of metallic salts; 3. colored reserves capable of assuming different tints in the dyeing; 4. reserves with mordants, for the cloth to be afterwards subjected to a dyeing bath, whereby variously colored figures are brought up on a blue ground, so as to resemble the mineral called *lazulite;* whence the name *lapis* or lapis lazuli.

1. The fatty resists are employed in the printing of silk; which see *infra.*

2. With regard to reserves the following general observations may be made. After printing-on the paste, the goods must be hung up in a chamber, rather humid than too dry, and left there for a certain time, more or less, according to the nature of the reserve. In dipping them into the blue vat, if the reserve be too dry, it is apt to swell, scale off, and vitiate the pattern. This accident is liable to happen also when the vat is deficient in lime, especially with deep blues.

1. *Simple white resist paste* for a full body of blue.

Take 1 gallon of water, in which are to be dissolved,
1 pound of binacetate of copper (distilled verdigris), and 3 lbs. of sulphate of copper.
This solution is to be thickened with
2 lbs. of gum senegal, 1 lb. of British gum, and 4 lbs. of pipe-clay; adding afterwards, 2 ounces of nitrate of copper—as a deliquescent substance.

2. *White reserve for light blues.*

Take 1 gallon of water, in which dissolve
4 ounces of binacetate of copper,
1 lb. of sulphate of copper; and thicken this solution with
2 lbs. of gum senegal, 1 lb. of British gum, and 4 lbs. of pipe-clay.

3. *White reserve for the cylinder machine.*

Take 1½ gallons of water; in which dissolve
2½ lbs. of binacetate of copper,
10 lbs. of sulphate of copper; and add to the solution
6 lbs. of acetate of lead; then thicken with
10 lbs. of gum; adding afterwards 10 lbs. of sulphate of lead.

After printing-on this reserve, the goods are to be hung up for two days, then dipped till the proper blue tint be obtained. Finally they must be winced through dilute sulphuric acid to clear up the white, by removing the cupreous tinge.

3. Colored reserves.

1. *Chamois reserve.*

Take 1 gallon of the chamois bath (No. 1, page 321, at bottom); to which add
8 ounces of nitrate of copper,
24 ditto of muriate of zinc; thicken with
6 pounds of pipe-clay, and 3 pounds of gum senegal.

After printing-on this paste, the goods must be hung up for five or six days in a somewhat damp room. Then after having dipped them in the vat, they are to be steeped in water for half an hour, and slightly washed. Next wince for half an hour, through water at 100° F. containing 2 pounds of soda crystals per 30 gallons. Rinse and dry.

2. *Chrome yellow reserve.*

Take 1 gallon of water; in which dissolve
3 lbs. of nitrate of lead,
1 lb. of binacetate of copper; to the solution, add
½ lb. of subacetate of lead; and thicken the mixed solution with
3 lbs. of gum.
6 lbs. of pipe-clay. Grind all the ingredients together, and pass through a searce.

After treating the goods as in No. 1, they must be winced for half an hour in a solution containing 5 ounces of bichromate of potash, per piece of calico, and also in a dilute muriatic bath, till the chrome yellow becomes sufficiently bright.

A chrome orange reserve may be made by introducing a larger proportion of subacetate of lead, and passing the reserve printed goods through weak milk of lime, as already prescribed for producing an orange by chrome.

The basis of the resist pastes used at Manchester is sometimes of more complex composition than the above; since, according to the private information I received from an extensive calico printer, they contain china clay (instead of pipe-clay, which often contains iron), strong solution of sulphate of copper, oil, tallow, and soap; the whole incorporated by trituration with heat.

In the Lancashire print-works, a little tartaric acid is added to the nitrate of lead, which prevents the color from taking a dingy cast.

4. *Reserves with mordants*, or the lazulite style.

1. *Black upon a blue ground.*

At Manchester the black pattern is printed-on with a mixture of iron liquor and extract of logwood, and the resist paste by the cylinder machine; in France the black is given by the following recipe:—

Take 1 gallon of decoction of galls of spec. grav. 1·04, mixed and boiled into a paste with
14 ounces of flour; into the paste, when nearly cold, there are added,
8 ounces of an acetated peroxyde of iron, made by adding 1 lb. acetate of lead to 3 lbs. of nitrate of iron, spec. grav. 1·56.
½ ounce of gallipoli oil.

This topical black forms a fast color, and resists the fine blue vat, weak potash ley bichromate of potash, boiling milk of lime, dunging, and maddering.

The preceding answers best for the block; the following for the cylinder,—

2. Take 1 gallon decoction of galls of spec. grav. 1·056.
    18 ounces of flour, mix, boil into a paste, to which, when cool, add
    8 ounces of the aceto-nitrate of iron of the preceding formula, and
    1 quart of iron liquor of spec. grav. 1·110.

In Lancashire a little prussiate of potash is sometimes added to nitrate of iron and decoction of logwood; and the goods are after washing, &c. finished by passing through a weak solution of bichromate of potash. The chromic acid gives depth and permanence to the black dye, being supposed to impart oxygen to the iron, while it does not affect any of the other colors that may happen to be impressed upon the cloth, as solution of chloride of lime would be apt to do. The solution of the bichromate deepens the spirit purples into blacks, and therefore with such delicate dyes becomes a very valuable application. This interesting fact was communicated to me by an eminent calico-printer in Lancashire.

Having premised the composition of the topical black dye, we are now prepared to apply it in the lazulite style.

1. *Black resist.*

Take 1 gallon of the above black without the flour,
    2 ounces of sulphate of copper,
    1 ounce of muriate of ammonia, dissolve and thicken with
    4 pounds of pipe-clay and 2 pounds of gum.

Another good formula is the following:—

Take 1 gallon of iron liquor of 1·056 spec. grav.; dissolve in it,
    2 ounces of binacetate of copper,
    8 ounces of sulphate of copper; and thicken as just described.

2. *Puce reserve* paste, contains acetate of alumina mixed with the iron liquor.

3. *Full red reserve.*

Take 1 gallon of acetate of alumina, (made with 50 gallons water, 100 lbs. alum, 10 lbs. soda crystals, and 100 lbs. acetate of lead; the supernatant liquid being of spec. grav. 1·085;) dissolve in it
    4 ounces of corrosive sublimate; thicken with
    2 pounds of gum senegal,
    4 pounds of pipe-clay, and mix in 8 ounces of gallipoli oil.

4. *Reserve paste for a light red.*

Take 1 gallon of the weaker sulpho-acetate of alumina formerly prescribed; dissolve in it
    4 ounces of corrosive sublimate; and thicken with
    4 pounds of pipe-clay, and 2 pounds of gum; adding to the mixture
    8 ounces of oil.

5. *Neutral resist paste.*

Take 1 gallon of water; in which dissolve,
    3¼ lbs. of binarseniate of potash, and
    12 ounces of corrosive sublimate; thicken with
    3 lbs. of gum, and 6 lbs. of pipe-clay, adding to the paste 16 ounces of oil.

6. *Carmelite reserve paste.*

Take 1 half gallon of acetate of alumina, spec. grav. 1·014; (see second aluminous mordant, p. 318.)
    1 half gallon iron liquor of spec. grav. 1·027; dissolve in them
    4 ounces of sulphate of copper, 4 ounces of verdigris, and 1 ounce of nitrate of copper; thicken with
    2 lbs. of gum,
    4 lbs. of pipe-clay.

7. *Neutral reserve paste.*

Take 1 gallon of water; dissolve in it,
    44 ounces of binarseniate of potash, and
    12 ounces of corrosive sublimate; thicken with
    3 lbs. of gum,
    6 lbs. of pipe-clay,
    16 oz. of oil.

To explain fully the manipulation of the lazulite style, we shall suppose that the calicoes are printed with the following reserves, taken in their order:—

1. Black reserve, No. 1. above.
2. Full red reserve, No. 3.
3. Light red reserve, No. 4.
4. Neutral reserve, No. 7.

Four days after printing-on these reserves, the goods must be twice dipped in the blue vat, ten minutes in and ten minutes out each time; but more dips may be given according to the desired depth of the shade. The cloth must be afterwards rinsed in running water for half an hour. The next process is to remove the paste; which is done by wincing the goods in a bran bath, lowered to 150°, during twenty minutes. They are then winced for five minutes in a bath of water slightly sharpened with vinegar. When well cleansed they are ready for the madder bath. The *lapis* goods are finally cleared in a bran bath, by exposure on the grass, and a soap boil.

The lazulite style is susceptible of many modifications.

8. *Deep blue ground*, with light blue, carmelite, and white figures.
   1. Print-on *the white* reserve, No. 1.
   2. Dip in the strongest blue vat; rinse and dry.
   3. Ground-in with the block, the carmelite reserve (containing the mixed acetates of iron and alumina.)
   4. Ground-in the neutral reserve.
   5. Dip for the light blue; rinse.
   6. Dung, dye, and clear, as above.

By varying the proportions of the reserve mordants, and the dye-stuffs, as madder, quercitron, &c. a great variety of effects may be produced.

9. *Deep green ground*, with buff and white figures.
   1. Print-on the white reserve.
   2. Dip in the blue vat; rinse and dry.
   3. Pad in the buff liquor, as formerly prescribed.
   4. Ground in upon the buff spots, the discharge No. 2, presently to be described.
   5. Wash away the paste in chalky water.
   6. Wince through a boiling alkaline ley, to raise the buff iron color.

IV. *The Discharge style; first*, of simple discharges.

1. *Discharge for block printing.*

Take 1 gallon of lemon or lime-juice, of spec. grav. 1·09, in which dissolve
1 pound of tartaric acid,
1 pound of oxalic acid, and thicken the solution with
4 pounds of pipe or china clay, and 2 pounds of pulverized gum; as soon as the gum is dissolved, the mixture must be put through a searce.

2. Another discharge is made of half the above acid strength.
3. A third with one half of the solid acids of the second.
4. Take 1 gallon of water, in which dissolve with heat
1 pound of cream of tartar, adding, to facilitate the solution,
1 pound of warm sulphuric acid of spec. grav. 1·7674; after 24 hours mix
4 lbs. of pipe or China clay, and three lbs. of gum, with the decanted clear liquor.
In some cases British gum is used alone, as a thickener.
5. Discharge for the cylinder machine.

Take 1 gallon of lime-juice, of spec. grav. 1·085; dissolve in it
3 pounds of tartaric acid, and one pound of oxalic acid; thicken with
6 pounds of gum senegal, or 5 pounds of British gum.

6, 7. A stronger and weaker discharge is made of the same materials; and one is made without the tartaric acid.

Second; combination of discharges with mordants.

1. *Black, red, lilach, and white figures upon an olive ground.*

The olive being given in a madder bath, and the ground well whitened (see MADDER), the cloth is padded in a weak buff mordant; and upon the parts that are to remain white, the weakest simple discharge No. 3 is printed-on by the cylinder; (in some works the discharge paste is applied and made dry before padding through the iron liquor;) the goods are cleared of the paste in a tepid chalky water, then dyed in a quercitron bath, containing a little glue, and cleared in a bran bath.

Discharge mordants upon mordants may be regarded as a beautiful modification of the preceding style. *Example.*

A violet ground or impression, with red and white.

1. Pad with an acetate of iron of 1·004; or print-on with the cylinder, iron liquor of 027 thickened with British gum.
2. Print-on a red mordant, strongly acidulated with lime-juice of 1·226.
3. Ground in the discharge No. 2; dry.
4. Clear off the paste in chalky water.
5. Dung, madder, and brighten.
6. Ground-in the topical colors at pleasure.

V. China blues.

Take 16 pounds of coarsely ground indigo, and
4 pounds of sulphuret of arsenic; dissolve 22 pounds of sulphate of iron in 6 gallons of water; introduce these three matters into the indigo mill, and grind them fo

three days. If it be wished to have a thickened blue, this mixture must have pounded gum added to it; but if not, 5 gallons of water are added. This color may be called blue No. 1.

The following table exhibits the different gradations of China blue:—

Course.	Quantity by measure of No. 1.	Quantity by measure of water or mucilage.
No. 1	1	0
2	11	1
3	10	2
4	8	4
5	6	6
6	4	8
7	2	10
8	2	12
9	2	14
10	2	16
11	2	18
12	2	20

I shall now give examples of working this style by the block and cylinder:—

Impression of a single blue with small dots.

For the block, blue No. 5, thickened with starch.

For the cylinder, No. 4, thickened with gum.

Impression of two different blues with the block.

First blue, No. 4, with starch.

Second blue, No. 9, with gum.

Impression of three blues with the block.

First blue, No. 5, with starch.

Second blue, No. 7, with starch.

Third blue, No. 10, with gum.

After printing-on the blues, the pieces are hung up for two days, in a dry and airy place, but not too dry; then they are dipped as follows:—Three vats are mounted, which may be distinguished by the numbers 1, 2, 3.

No. 1. 300 pounds of lime to 1,800 gallons of water.

No. 2. Solution of sulphate of iron of spec. grav. 1·048.

3. Solution of caustic soda of spec. grav. 1·055; made from soda crystals, quicklime, and water, as usual.

The pieces being suspended on the frames, are to be dipped in the first vat, and left in it ten minutes; then withdrawn, drained for five minutes; next plunged into the second vat for ten minutes, and drained also for five, &c. These operations will be most intelligible when put into the form of a table:—

Dip in the 1st vat.	During 10 minutes.	Drain during 5 minutes.
2	—	—
1	—	—
2	—	—
3	—	—
2	—	—
1	—	—
2	—	—
1	—	—
2	—	—
3	—	—

In the dipping of China blues, care should be taken to swing the frames during the operation; and when the last dip is given, the piece is to be plunged upon its frame into a fourth vat, containing dilute sulphuric acid of spec. grav. 1·027. This immersion is for the purpose of removing the oxyde of iron, deposited upon the calico in the alternate passages through the sulphate of iron and lime vats. They are then rinsed an hour in running water, and finally brightened in the above dilute sulphuric acid, slightly tepid. Sometimes they are subjected to a soap bath, at the temperature of 120°. By the addition of nitrate of lead to the indigo vat, the blue becomes more lively. Some use the roller dyeing apparatus for running the pieces through the respective baths instead of the square frames. (See WINCING.) But the frame-dip gives the most evenly dyes, and preserves the vats in good condition for a much longer time.

The various phenomena which occur in the dipping of China blues are not difficult of explanation with the lights of modern chemistry. We have, on the one hand, indigo and sulphate of iron alternately applied to the cloth; by dipping it into the lime, the blue is deoxydized, because a film of the sulphate of iron is decomposed, and protoxyde of iron comes forth to seize the oxygen of the indigo, to make it yellow-green, and soluble, at the same time, in lime-water. Then, it penetrates into the heart of the fibres, and, on exposure to air, absorbs oxygen, so as to become insoluble and fixed within their pores. On dipping the calico into the second vat of sulphate of iron, a layer of oxyde is formed upon its whole surface, which oxyde exercises an action only upon those parts that are covered with indigo, and deoxydizes a portion of it; thus rendering a second dose soluble by the intervention of the second dip in the lime-bath. Hence we see that while these alternate transitions go on, the same series of deoxydizement, solution, and re-oxydizement recurs; causing a progressively increasing fixation of indigo within the fibres of the cotton. A deposite of sulphate of lime and oxyde of iron necessarily falls upon the cloth, for which reason the frame should be shaken in the lime-water vat, to detach the sulphate; but, on the contrary, it should be held motionless in the copperas bath, to favor the deposition of as much protoxyde upon it as possible. These circumstances serve to account for the various accidents which sometimes befall the China blue process. Thus the blues sometimes scale off, which may proceed from one of two causes :—1. If the goods are too dry before being dipped, the color swells, and comes off in the vats, carrying along with it more or less of indigo. 2. If the quantity of sulphate of lime formed upon the cloth be considerable, the crust will fall off, and take with it more or less of the blue; whence arise inequalities in the impression. The influence of temperature is important; when it falls too low, the colors take a gray cast. In this case it should be raised with steam.

VI. The decoloring or *enlevage* style; not by the removal of the mordant, but the destruction of the dye. The acid, which is here mixed with the discharge paste, is intended to combine with the base of the chloride, and set the chlorine free to act upon the color. Among the topical colors for this style are the following :—

1. *Black.*—Take one gallon of iron liquor of spec. grav. 1·086.
   One pound of starch; boil together, and while the paste is hot, dissolve in it
   One pound of tartaric acid in powder; and when cold, add
   Two pounds of Prussian blue, prepared with muriatic acid, see p. 321.
   Two ounces of lamp black, with four ounces of oil.
2. *White discharge.*—Take one gallon of water, in which dissolve
   One pound and a half of oxalic acid,
   Three pounds of tartaric acid; add
   One gallon of lime-juice of spec. grav. 1·22; and thicken with
   Twelve pounds of pipe clay, and six pounds of gum.
3. *Chrome-green discharge.*—
   Take one gallon of water, thicken with 18 ounces of starch; boil and dissolve in the hot paste;
   Two pounds and a half of powdered nitrate of lead,
   One pound and a half of tartaric acid,
   Two pounds of Prussian blue, as above.
4. *Blue discharge.*—Take one gallon of water, thicken with
   18 ounces of gum; while the boiled paste is hot, dissolve in it
   Two pounds of tartaric acid, and mix one pound of Prussian blue.
5. *Chrome-yellow discharge.*—This is the same as the chrome-green given above, but without the Prussian blue.
6. *A white discharge on a blue ground* requires the above white discharge to be strengthened with 8 ounces of strong sulphuric acid, per gallon.
7. *White discharge for Turkey red* needs to be very strong.
   Take one gallon of lime-juice of sp. grav. 1·086; dissolve in it
   Five pounds of tartaric acid; thicken with
   Eight pounds of pipe-clay, four pounds of gum; then dissolve in the mixture
   Three pounds of muriate of tin in crystals; and add, finally,
   Twenty-four ounces of sulphuric acid.
8. *Yellow discharge for Turkey red.*—
   Take one gallon of lime-juice of spec. grav. 1·086; in which dissolve
   Four pounds of tartaric acid,
   Four pounds of nitrate of lead; thicken the solution with
   Six pounds of pipe-clay, and three pounds of gum.
9. *For green discharge*, add to the preceding 24 ounces of Prussian blue, as above.

The decoloring or chlorine bath is usually formed of wood lined with lead, and has an area of about 5 feet square, with a depth of 6 feet. A square frame, mounted with a horizontal series of rollers at top and bottom, may be let down by cords, at

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pleasure, into the cistern. The pieces are introduced and guided in a serpentine path, round the upper and lower rollers alternately, by a cord.

This bath is filled with a solution of chloride of lime, of the spec. grav. 1·045, whose decoloring strength is 65° by Gay Lussac's indigo chlorometer. It ought to be made turbid by stirring before putting in the goods, which should occupy three minutes in their passage. The piece is drawn through by a pair of squeezer cylinders at the end of the trough, opposite to that at which the piece enters. With black, white, and blue impressions of all shades, the goods are floated in a stream of water for an hour; then rinsed and dried. When there is yellow or green, the pieces must be steeped in water, then merely washed by the wince, and passed through solution of bichromate of potash, containing from 3 to 5 ounces of the salt per piece. Here the pieces are winced during 15 or 20 minutes, rinsed, and next passed through dilute muriatic acid to clear the ground; then rinsed and dried.

Discharge by the intervention of the chromic acid.

After having dipped the pieces to the desired shade, they are padded in a solution of bichromate of potash; dried in the shade without heat; and then printed with the following mordant:—

Take 1 gallon of water; dissolve in it
2 pounds of oxalic and 1 pound of tartaric acid; thicken with
6 pounds of pipe-clay, and 3 pounds of gum; lastly, add
8 ounces of muriatic acid.

After the impression, the pieces are winced in chalky water, at 120° F., then washed, and passed through a dilute sulphuric acid.

M. Daniel Kœchlin, of Mulhausen, the author of this very ingenious process, considers the action of the bichromate here as being analogous to that of the alkaline chlorides. At the moment that the block applies the preceding discharge to the bichromate dye, there is a sudden decoloration, and a production of a peculiar odor.

The pieces padded with the bichromate must be dried at a moderate temperature, and in the shade. Whenever watery solutions of chromate of potash and tartaric acid are mixed, an effervescence takes place, during which the mixture possesses the power of destroying vegetable colors. This property lasts no longer than the effervescence.

VII. *Steam colors.*—This style combines a degree of brilliancy with solidity of color, which can hardly be obtained in any other way except by the chints dyes. The steam apparatus employed for fixing colors upon goods, may be distributed under five heads:—1. the column; 2. the lantern; 3. the cask; 4. the steam-chest; and, 5. the chamber.

The column is what is most generally used in this country. It is a hollow cylinder of copper, from three to five inches in diameter, and about 44 inches long, perforated over its whole surface with holes of about one sixteenth of an inch, placed about a quarter of an inch asunder. A circular plate, about 9 inches diameter, is soldered to the lower end of the column, destined to prevent the coil of cloth from sliding down off the cylinder. The lower end of the column terminates in a pipe, mounted with a stop-cock for regulating the admission of steam from the main steam-boiler of the factory. In some cases, the pipe fixed to the lower surface of the disc is made tapering, and fits into a conical socket, in a strong iron or copper box, fixed to a solid pedestal; the steam pipe enters into one side of that box, and is provided, of course, with a stop-cock. The condensed water of the column falls down into that chest, and may be let off by a descending tube and a stop-cock. In other forms of the column, the conical junction pipe is at its top, and fits there into an inverted socket connected with a steam chest, while the bottom has a very small tubular outlet, so that the steam may be exposed to a certain pressure in the column, when it is incased with cloth.

The pieces, after being printed with the topical colors presently to be described, and dried, are lapped round this column, but not in immediate contact with it; for the copper cylinder is first enveloped in a few coils of blanket stuff; then with several coils of white calico; next with the several pieces of the printed goods, stitched endwise; and lastly, with an outward mantle of white calico. In the course of the lapping and unlapping of such a length of webs, the cylinder is laid in a horizontal frame, in which it is made to revolve. In the act of steaming, however, it is fixed upright, by one of the methods above described. The steaming lasts for 20 or 30 minutes, according to the nature of the dyes; those which contain much solution of tin admit of less steaming. Whenever the steam is shut off, the goods must be immediately uncoiled, to prevent the chance of any aqueous condensation. I was much surprised, at first, on finding the unrolled pieces to be free from damp, and requiring only to be exposed for a few minutes in the air, to appear perfectly dry. Were water condensed during the process, it would be apt to make the colors run.

Steam colors are all topical, though, for many of them, the pieces are previously padded with mordants of various kinds. Some manufacturers run the goods before printing them through a weak solution of the perchloride of tin, with the view of brightening all the colors subsequently applied or raised upon them. I shall now illustrate steam calico-printing by some examples, kindly furnished me by a practical printer near Manchester, who conducts a great business with remarkable success.

Steam blue.—Prussiate of potash, tartaric acid, and a little sulphuric acid, are dissolved in water, and thickened with starch; then applied by the cylinder, dried at a moderate heat, and steamed for 25 minutes. They are rinsed and dried after the steaming. The tartaric acid, at a high temperature, decomposes here a portion of the ferrocyanic acid, and fixes the remaining ferrocyanate of iron (Prussian blue) in the fibre of the cloth. The ground may have been previously padded and dyed; the acids will remove the mordant from the points to which the above paste has been applied, and bring out a bright blue upon them.

Steam purple.—This topical color is made by digesting acetate of alumina upon ground logwood with heat; straining, thickening with gum senegal, and applying the paste by the cylinder machine.

Steam pink.—A decoction of Brazil-wood with a small quantity of the solution of muriate of tin, called, at Manchester, new tin crystals,* and a little nitrate of copper to assist in fixing the color; properly thickened, dried, and steamed for not more than 20 minutes, on account of the corrosive action of muriate of tin when the heat is too strong.

Cochineal pink.—Acetate of alumina is mixed with decoction of cochineal, a little tartaric acid and solution of tin; then thickened with starch, dried, and steamed.

Steam brown.—A mixed infusion of logwood, cochineal, and Persian berries, with cream of tartar, alum (or acetate of alumina), and a little tartaric acid, thickened, dried, and steamed.

Green, blue, chocolate, with white ground, by steam.—Prussiate of potash and tartaric acid, thickened, for the blue; the same mixture with berry-liquor and acetate of alumina, thickened, for the green; extract of logwood with acetate of alumina and cream of tartar, thickened, for the chocolate. These three topical colors are applied at once by the three-color cylinder machine; dried and steamed. Though greens are fixed by the steam, their color is much improved by passing the cloth through solution of bichromate of potash.

In France, solution of tin is much used for steam colors.

VIII. *Spirit or fancy colors.*—These all owe their vivacity, as well as the moderate degree of permanency they possess, to their tin mordant. After printing-on the topical color, the goods must be dried at a gentle heat, and passed merely through the rinsing machine. Purple, brown, or chocolate, red, green, yellow, blue, and white discharge; any five of these are printed on at once by the five-color cylinder machine. See RINSING MACHINE.

Chocolate is given by extract of Brazil-wood, extract of logwood, nitro-muriate of tin, with a little nitrate of copper: all mixed, thickened, and merely printed-on.

Red, by extract of Brazil-wood and tin, with a little nitrate of copper.

Green, by prussiate of potash, with muriate of tin and acetate of lead, dissolved, thickened, and printed-on.

The goods after rinsing must be passed through solution of bichromate of potash, to convert the Prussian blue color into green, by the formation of chrome yellow upon it.

Blue.—Prussian blue ground up with solution (nitromuriate) of tin; thickened, &c.

Yellow.—Nitrate of lead dissolved in solution of tartaric acid, thickened, tenderly dried, passed through the bichromate vat or padding machine, washed and dried.

This yellow is pretty fast; though topical, it can hardly, therefore, be called a fancy color.

When *purple* is to be inserted instead of the above blue, extract of logwood with tin is used in the place of the Prussian blue. Tartaric acid is a useful addition to tin in brightening fancy colors.

Chocolate.—A good topical chocolate is made by digesting logwood with liquid acetate of alumina, adding a little cream of tartar to the infusion; thickening, applying by the cylinder, drying, washing, then passing through solution of bichromate of potash, which serves to darken and fix the color.

I shall conclude my account of the printing of cotton goods with some miscellaneous formulæ, which were given me by skilful calico-printers in Lancashire.

Prussian blue is prepared for topical printing by grinding it in a handmill, like that for grinding pepper or coffee, and triturating the powder with solution of muriate of tin.

Green.—The deoxydized indigo vat liquor is mixed with a little pearlash, and thickened with gum. This is applied by the cylinder or block to goods previously padded with nitrate of lead; the goods, after being dried, are passed through milky lime water, rinsed, and then winced or padded through the bichromate of potash bath.

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* This preparation is made by adding 3 lbs. of sal ammoniac to 1 gallon of solution of tin (*see* SCARLET DYE, and TIN), evaporating, and crystallizing. The sal ammoniac seems to counteract the separation of the tin by peroxydizement.

Another green.—Nitrate of lead, prussiate of potash, and tartaric acid, dissolved, and mixed with a little sulphate, nitrate, and muriate of iron; this mixture is either thickened for cylinder printing, or used in its liquid state in the padding trough. The goods subjected to one of these two processes are dried, padded in weak solution of carbonate of potash, which serves to precipitate the oxyde of lead from the nitrate; they are finally padded with bichromate of potash, which induces a yellow upon the blue, constituting a green color of any desired tint, according to the proportion of the materials.

Chocolate and black, with white discharge; a fast color.—The cloth is padded with acetate of alumina, and dried in the hot-flue; it is then passed through a two-color machine, the one cylinder of which prints-on lime-juice discharge, thickened with gum senegal; the other a black topical dye (made with logwood extract and iron liquor). The cloths are now hung up to be aired during a week, after which they are dunged, and dyed up with madder, fustic, and quercitron bark, heated with steam in the bath.

Blue, white, and olive or chocolate.—1. Pad with the aluminous mordant; 2. Apply thickened lemon-juice for discharge by the cylinder; 3. Dung the goods after they are thoroughly dried; 4. Pass them through the bath of madder, fustic, and quercitron, which dye a brown ground, and leave the discharge points white; then print-on a reserve paste of China clay and gum with sulphate of copper; dry, dip in the blue vat, which will communicate an olive tint to the brown ground; or a chocolate, if madder alone had been used.

When a black ground is desired, with white figures, the acid discharge paste should be printed-on by the cylinder, and dried before the piece is padded in the iron liquor. By following this plan the whites are much purer than when the iron is first applied.

Green, black, white.—The black is first printed-on by a mixture of iron liquor, and infusion (not decoction) of logwood; then resist or reserve paste is applied by the block, and dried; after which the goods are blued in the indigo vat, rinsed, dried, passed through solution of acetate of lead; next, through milky lime-water; lastly, through a very strong solution of bichromate of potash.

Turkey red, black, yellow.—Upon Turkey red cloth, print with a strong solution of tartaric acid, mixed with solution of nitrate of lead, thickened with gum; dry. The cloth is now passed through the chloride of lime bath, washed, and chromed. Lastly, the black is printed-on by the block as above, with iron liquor and logwood.

Black ground dotted white, with red or pink and black figures.—1. Print-on the lime-juice discharge-paste by the cylinder; dry; 2. Then pad with iron liquor, containing a little acetate of alumina, and hang up the goods for a few days to fix the iron; 3. Dye in a logwood bath to which a little madder has been added; clear with bran. The red or pink is now put in by the block, with a mixture of extract of Brazil-wood, nitromuriate of tin, and nitrate of copper, as prescribed in a preceding formula.

Orange or brown; black; white; pink.—The black is topical, as above; it is printed-on, as also the lemon-juice discharge and red mordant, with muriate of tin (both thickened), by the three-color machine. Then, after drying the cloth, a single-cylinder machine is made to apply in diagonal lines to it a mixture of acetate of iron and alumina. The cloth, being dried and dunged, is next dyed in a bath of quercitron, madder, and fustic.

Here the orange is the result of the mordant of tin and alumina; the brown, of the alumina and iron; white, of the citric acid discharge. The tin mordant, wherever it has been applied, resists the weaker mordant impressed in the diagonal lines. The pink is blocked-on at the end.

Orange brown, or aventurine; black and white.—The topical black (as above) and discharge lemon-juice, are printed-on by the two-color machine; then the cloth is subjected to the diagonal line cylinder, supplied with the alumino-iron mordant. The cloth is dried, dunged, and dyed in a bath of bark, madder, and fustic.

The manganese or *solitaire* ground admits of a great variety of figures being easily brought upon it, because almost every acidulous mordant will dissolve the oxyde of manganese from the spot to which it is applied, and insert its own base in its place; and of course, by dyeing such mordanted goods in various baths, any variety of colored designs may be produced. Thus, if the paste of nitrate of lead and tartaric acid solution be applied, and the goods after drying be passed first through lime-water, and then through a chrome bath, bright yellow spots will be made to appear upon the bronze ground.

Manganese bronze, buff and green; all metallic colors.—Pad-on the manganese solution, and dry; apply the aceto-sulphate of iron, of spec. grav. 1·02, and Scheele's green (both properly thickened), by the two-color machine. The goods are next to be dried, and padded through a cold caustic ley of spec. grav. 1·086. They are then rinsed, and passed through a weak solution of chloride of lime, to raise the bronze, again rinsed, and passed through a solution of arsenious acid to raise the green.

Scheele's green for the calico-printer is made as follows :—

Take 1 gallon of water, in which dissolve with heat,

5 pounds of sulphate of copper, and 1 pound of verdigris. When the two salts are dissolved, remove the kettle from the fire, and put into it 1 quart of solution of nitrate of copper, and 5 pounds of acetate of lead. Stir the mixture to facilitate the decomposition, and allow the pigment to subside.

It must be thickened with 2½ lbs. of gum per gallon, for pencilling; or 12 oz. of starch for the block. The goods printed with this paste are to be winced through a caustic ley, till a fine sky-blue be produced; then washed well and rinsed. They are now to be passed through water, containing from half an ounce to an ounce of white arsenic per piece; 4 turns are sufficient; if it be too long immersed it will take a yellow tint.

Catechu has been considerably employed by calico-printers of late years, as it affords a fine permanent substantive brown, of the shade called *carmelite* by the French. The following formula will exemplify its mode of application :—

Take 1 gallon of water;

1 pound of catechu in fine powder; reduce by boiling to half a gallon, pass the decoction through a fine sieve, and dissolve in it 4 ounces of verdigris; allow it then to cool, and thicken the solution with 5 ounces of starch; while the paste is hot, dissolve in it 5 ounces of pulverized muriate of ammonia.

Print-on this paste, dry, and wash. It is a fast color.

I shall subjoin the prescriptions for two fancy cochineal printing colors.

Amaranth by cochineal.—Pad the pieces in the aluminous mordant of spec. grav. 1·027, page 319.

Dry in the hot flue; and after hanging up the goods during 3 days, wince well through chalky water, and then dye, as follows :—

For each piece of 28 or 30 yards, 8 ounces of cochineal are to be made into a decoction of 2 gallons in bulk, which is to be poured into a kettle with a decoction of 3 ounces of galls, and with two ounces of bran. The pieces are to be entered and winced as in the madder bath, during two hours and a half; then washed in the dash wheel. On mixing with the amaranth bath a certain quantity of logwood, very beautiful lilachs and violets may be obtained.

Mixture of quercitron and cochineal.—Pad in the aluminous mordant, and dye with 2 lbs. of quercitron, and 4 ounces of cochineal, when a capuchin color will be obtained. If we pad with the following mordant, viz., 1 gallon of acetate of alumina of 1·056 spec. grav., and 1 of iron liquor of 1·02 spec. grav., and dye with 1 pound of quercitron, and 1 ounce of cochineal, we shall obtain a shade like boot tops, of extreme vivacity.

Two ounces of cochineal will print a long piece of calico with rich pink figures, having acetate of alumina for a mordant. As the ground is hardly tinged by the dye, it neither needs nor admits of much clearing.

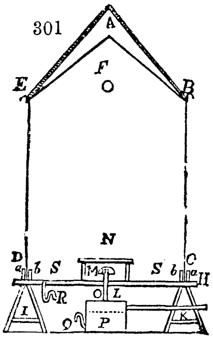
I have already mentioned that goods are sometimes padded with solution of perchloride of tin before printing-on them the steam colors, whereby they acquire both permanence and vivacity. I have also stated that the salts of tin at a high temperature are apt to corrode the fibre of the stuff, and therefore must be used with discretion. This danger is greatly lessened by adding to the perchloride of tin a sufficient quantity of caustic potash ley to form a stannate of potash. The goods are padded through this substance, diluted with water, dried with a moderate heat, and then immersed in very dilute sulphuric acid, which saturates the potash, and precipitates the tin oxyde within the pores of the cloth. Calico thus prepared affords brilliant and permanent colors by the steam process, above described.

Printing of silks or woollen stuffs, such as merinoes and mousselin de laine, as also of mixed stuffs of silk and wool, such as chalys.—All these prints are applied, not by the cylinder but the block, and are fixed by the application of steam in one of four ways; 1. By the *lantern;* 2. By the *cask;* 3. By the *chest;* or, 4. By the *chamber.*

1. *By the lantern.*—In this mode of exposure to steam, the goods are stretched upon a frame; and therefore the apparatus may be described under two heads; the lantern and the frame. The former is made of copper, in the shape of a box A B C D E, *fig.* 301, open below, and with a sloping roof above, to facilitate the trickling down of the water condensed upon the walls. The sides B C D E are 4½ feet high, 6 feet long, and 4 feet wide. The distance of the point A from the line E B is 2 feet. At F is a brass socket, which may be stopped with a cork; and there is a similar one at the other side. This kind of penthouse may be raised by means of a pulley with cords fixed to the four angles of the roof E B; and it rests upon the table G H, a little larger than the area of the box, which stands upon the four feet I K. Round the borders of the table there is a triangular groove *a b*, for receiving the lower edges of the box, and it is stuffed steam-tight with lists of cloth. Through the centre of the table, the two-inch steam pipe M

passes; it is surmounted with a hemispherical rose pierced with numerous holes for the equal distribution of the steam. Right above it, a disc N is placed upon four feet. The tube L communicates with a box P, which has a syphon Q to let off the condensed water. At the upper part of this box the tube L terminates which brings the steam. The little table G H slopes towards the part G, where the syphon R is placed for drawing off the water.

301



The *frame* has such dimensions, that it may stand in the four corners of the table at S S, as pointed out by the dotted lines. The second part embraces an open square frame, which is formed by spars of wood 2 inches square, mortised together; and is 3 feet 8 inches wide, 5 feet 8 inches long, and 4 feet 3 inches high; it is strengthened with cross bars. Upon the two sides of its breadth, two rows of round brass hooks are placed, about half an inch apart; they are soldered to a copper plate fixed to uprights by means of screws.

Before hanging up the goods, a piece of cloth 3 feet 8 inches long, and 4 feet wide, is placed upon the row of hooks; and 3 feet of it are left hanging out.

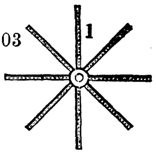
One foot within, the hooks pass through the cloth. A similar one is fitted to the other side. This cloth is intended to cover the goods hung upon the hooks; and it is kept straight by resting upon strings. The pieces are attached zig-zag from one hook to another. When the frame is filled, the bag is put within the cloths; it has the same rectangular shape as the frame. The pieces are in this way all incased in the cloth; a bit of it being also put beneath to prevent moisture affecting that part.

When shawls are framed, they are attached with pins; and if they be too large, they are doubled back to back, with the fringes at top.

These arrangements being made, the frame is set upon the table, the penthouse is placed over it, and the steam is admitted during from 35 to 45 minutes, according to circumstances. The orifice F is opened at first to let the air escape, and when it begins to discharge steam it is stopped. The frame is taken out at the proper time, the bag is removed, the cloths are lifted off, and the goods are spread out for airing. Three frames and six bags are required for a constant succession of work. The above apparatus is particularly suitable for silks.

2. *The drum.*—This is the most simple mode of steaming. The apparatus is a drum of white wood, 2 inches thick, *fig.* 302; the bottom is pierced with a hole which admits the steam-pipe F, terminating in a perforated rose. Four inches from the bottom there is a canvass partition E, intended to stop any drops of water projected from the tube F, and also to separate the condensed water from the body of the apparatus. The drum is covered in by a wooden head H, under which the goods are placed. It is made fast either by bolts, or by hooks, G G, thus ꝏ, to which weighted cords are hung. The frame 1, *fig.* 302, rests upon a hoop, *a a*, a few inches from the edge. The goods are hung upon the frame in the ordinary way, and then wrapped round with flannel. The frame is studded with pin points, like that of the indigo vat, fixed about 5 inches asunder. From 20 to 30 minutes suffice for one steaming operation. The upper part of the frame must be covered also with flannels to prevent the deposition of moisture upon it. At the bottom of the drum there is a stopcock to let off the condensed water. According to the size of the figure, which is 3 feet 2 inches, 50 yards may be hung up single; but they may be doubled on occasion.

303



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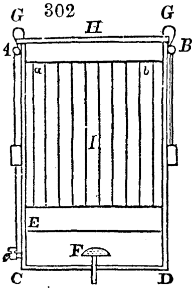

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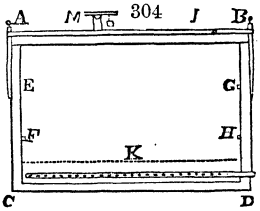
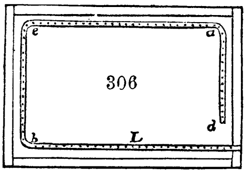


3. *The box.*—This steaming apparatus is convenient from the large quantity of goods admissible at a time: it answers best for woollen stuffs. From 12 to 16 pieces, of 36 yards each, may be operated upon at once; and from 240 to 260 shawls. It is formed of a deal box, A B C D, *fig.* 304, 4 feet wide, 6 long, and 3 high; the wood being 4 inches thick. It is closed by a cover of the same substance, I, which is made steam-tight at the edges by a list of felt. The lid is fastened down by 5 cross bars of iron, *a a a a a*, which are secured by screws, *c c c c c*, *fig.* 305. The ends of these cross bars are set into the notches, *b b b b b*, on the edge of the box. The safety valve M, *fig.* 304, is placed upon the lid. For taking off the lid, there are rings at the four

corners, *d d d d*, **bearing cords,** F F F F. These join at the centre into one, which passes over a pulley. Eight inches from the bottom of the box there is a horizontal canvass partition, beneath which the steam is discharged from the pipe L, *fig.* 306. There are two ledges, E F G H, at the sides for receiving the bobbins. The tube L runs round the box, as shown by the letters *d a e b:* the end *d* is shut; but the side and top are perforated with many holes in the direction towards the centre of the box. *Fig.* 305 shows the arrangement of the lower set of bobbins: that of the upper set is shown by the dotted lines: it is seen to be in an alternate position, one lying between two others. They are formed of pieces of deal 4 inches broad, 1 inch thick, and of a length equal to the width of the box. They are first wrapped round with 5 or 6 turns of doubled flannel or calico: the piece of goods is laid over it upon a table, and then wrapped round. At the end of the piece, several folds of the covering must be put, as also a roll of flannel. The two ends must be slightly tied with packthread. When these flat bobbins are arranged in a box, the steam is let on them, and continued about 45 minutes; it is then shut off, the lid is removed, and the pieces are unrolled.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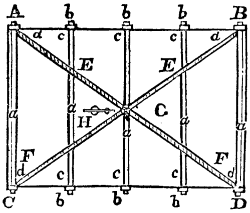

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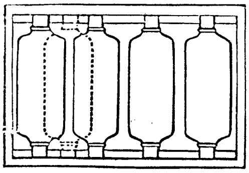
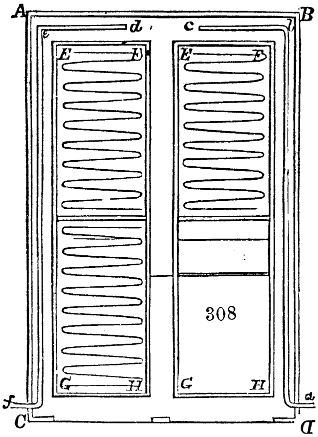


4. *The chamber.*—The interior height of the chamber, A B C D, *fig.* 308, is nine feet, the length 12 feet, and the breadth 9 feet. The steam is introduced into it by two pipes, *a b c*, *d e f*. Their two ends, *d c*, are shut; but their sides are all along perforated with small holes. The frames E F G H, E F G H, are moveable, and run upon rollers: they are taken out by front doors, which are made of strong planks, shut by sliding in slots, and are secured by strong iron bars and pressure screws. The cross rods, E F G H, are provided with hooks for hanging up the pieces. There is a safety-valve in the top of this large chamber. The dimensions of the frame are ten feet long, 3 feet wide, and 7 high. Three feet and a half from the upper part of the frame, a row of hooks is fixed for hanging on a double row of pieces, as shown in the figure. Over the frame, woollen blankets are laid to protect it from drops of water that might fall from the roof of the chamber. When the hooks are two thirds of an inch apart, 24 pieces, of 28 yards each, may be suspended at once. The period of steaming is from 45 to 60 minutes.


308

Muslins and silks do not require so high a temperature as woollen goods. When the stuffs are padded with color, like merinoes and chalys, they must not be folded together, for fear of stains, which are sometimes occasioned by the column in steam calico-printing, where the end which receives the first impression of the steam is seldom of the same shade as the rest of the roll of goods. The duration of the steaming depends upon the quantity of acid in the mordant, and of saline solution in the topical color; the more of which are present the shorter should be the steaming period. A dry vapor is requisite in all cases; for when it becomes moist, from a feeble supply or external condensation, the goods become streaky or stained by the spreading of the colors.

1. *Black figures* are given by decoction of logwood thickened with starch, to which a little oxalic acid is added while hot, and, after it is cold, neutralized solution of nitrate of iron.

2. *Dark blue for a ground.*—Decoction of logwood, and archil thickened with starch to which, while the paste is hot, a little soluble Prussian blue is added; and, when it is cold, neutralized nitrate of iron; see *supra.*

3. *Deep poppy or ponceau color.*—Cochineal boiled in starch water, with oxalic acid (or tartaric), and perchloride of tin.

4. *Rose.*—Cochineal infusion; oxalic acid; perchloride of tin; thickened with gum.

5. *Dark amaranth.*—Decoctions of archil and cochineal, thickened with starch: to the paste, alum and perchloride of tin are added.

6. *Capuchin color.*—Quercitron and cochineal thickened with starch; to the paste add oxalic acid and perchloride of tin.

7. *Annotto orange.*—Dissolve the annotto in soda ley, of spec. grav. 1·07, at a boiling heat; add aluminate of soda, and thicken with gum.

8. *Golden yellow.*—Decoction of Persian berries thickened with starch; to which some alum and muriate of tin are added, with a little perchloride of tin and oxalic acid.

9. *Lemon yellow.*—Persian berries; starch; alum.

10. An ammoniacal solution of cochineal is used for making many violet and mallow colors. It is prepared by infusing cochineal in water of ammonia for 24 hours; then diluting with water, heating to ebullition, and straining.

11. *Fine violet* is given by ammoniacal cochineal, with alum and oxalic acid; to which a little aceto-sulphate of indigo is added, and gum for thickening. The following blue may be used instead of the solution of indigo. The *mallow* tint is given by adding a little perchloride of tin to the above formula, and leaving out the blue.

12. *Dark blue.*—Soluble Prussian blue; tartaric acid; alum; thicken with gum.

13. *Emerald green.*—One quart of decoction, equivalent to 1 pound of Persian berries; 1 quart of infusion of quercitron, of spec. grav. 1·027; in which dissolve 12 ounces of alum in powder; and add 6 ounces of the following blue bath for greens; thicken with 20 ounces of gum.

14. Blue bath for greens. Half a gallon of water at 140° F., one pound of soluble Prussian blue, 3 ounces of tartaric acid, and 2 ounces of alum.

I. *Printing of Silks.*—1. *Of the madder style.* This is one of the most difficult to execute, requiring both much skill and experience. The first step is the removal of the gum. A copper being nearly filled with water, the pieces, tied up in a linen bag, are put into it, with a quarter of a pound of soap for every pound of silk, and are boiled for 3 hours. If the silk be Indian, half an ounce of soda crystals must be added. When the goods are taken out, they are rinsed in the river, then passed through water at 140° F., holding 8 ounces of crystallized soda in solution, as a scourer. They are next rinsed in cold water, and steeped in water very faintly acidulated with sulphuric acid, during 4 hours, then rinsed, and dried.

Preparation of Mordants.—1 gallon of boiling water; 2 pounds of alum; dissolve: 1 pound of acetate of lead; 4 ounces of sal-ammoniac; 1 of chalk; mix well together; after decomposition and subsidence, draw off clear.

1. *Red.*—1 gallon of the above mordant, thickened with 14 ounces of starch, and tinged with decoction of Brazil-wood. If dark red be wanted, dissolve, in a gallon of the above red, 4 ounces of sulphate of copper.

2. *Black.*—1 gallon of iron liquor, of 1·056 spec. grav.; thicken with 14 ounces of starch; and dissolve in the hot paste 2 ounces of sulphate of copper.

3. *Violet.*—Take 1 gallon of iron liquor of 1·04 spec. grav.;
2 ounces of cream of tartar; 2 ounces of nitre; 2 ounces of copperas;
1 ounce of alum: dissolve, and mix the solution with
1 gallon of gum water, containing 6 lbs. of gum.

4. *Puce.*—Half a gallon of red mordant; half a gallon of iron liquor of 1·07;
7 ounces of starch for thickening; color with logwood.

Manipulation of the above colors.—Print-on the black, then the puce, next the violet, and lastly the red. Dry in the hot flue, and 48 hours after the impression, wash away the paste. The copper employed for dyeing is of a square form: a boil is given with bran, at the rate of 4 lbs. per piece of the *foulards*: cold water is added to lower the temperature to 130° F. The pieces must be entered with the printed surface undermost, and winced for half an hour, taking care to keep them expanded and well covered with the liquor: they are then taken out and rinsed. When grounds are to be made on the foulards, 2 ounces of sumach must be added per piece.

Maddering.—Suppose 48 pieces are to be grounded with madder. 12 pounds of madder must be put into the copper, 1 pound of sumach, and 6 pounds of bran; the bath must be tepid when the pieces are entered: it must be heated to 104° F. in 20 minutes, and to the boiling point in an hour and a half. The goods must be briskly winced all the time, and finally turned out into cold water.

When they come out of the madder bath they are much loaded with color. They are cleared by a boil of half an hour in bran, then turned out into cold water, and rinsed. A copper must be now mounted with 3 pounds of soap, 1 ounce of solution of tin, and 2 pailsful of bran, in which the goods are to be boiled for half an hour, then rinsed, and passed through a very dilute sulphuric acid bath. Then rinse, and dry. By following this process, a light salmon ground is obtained.

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II. *Steam colors upon silk.*—The same plan of operations may be adopted here as is described for calico-printing; the main difference being in the method of mordanting the stuffs. After boiling in soap water, in the proportion of 4 ounces per pound of silk, the goods are washed in cold water, and then in hot water at 140°; they are next rinsed, passed through weak sulphuric acid, rinsed, squeezed between rollers, and afterwards steeped in a bath containing 8 ounces of alum per gallon, where they remain for four hours, with occasionally wincing. They are now rinsed and dried. The subsequent treatment resembles that of steam-color printed cottons.

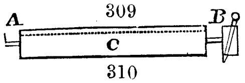
Black.—Take a gallon of decoction, made with 4 lbs. of logwood, with which
14 ounces of starch are to be combined : mix in
2 ounces of powdered nut-galls: boil, and pour the color into a pipkin containing
2 ounces of tartaric acid; 2 ounces of oxalic, both in powder, and
2 ounces of olive oil. Stir the color till it is cold, and add
8 ounces of nitrate of iron, and 4 ounces of nitrate of copper.

The red, violet, lilach, yellow colors, &c. are the same as for steam colors upon cotton. Topical colors are also applied without mordanting the silk beforehand. In this case a little muriate of tin is introduced. Thus, for

Yellow.—Take 1 gallon of a decoction, made with 4 lbs. of Persian berries: dissolve in it 8 ounces of salt of tin (muriate), and 4 ounces of the nitro-muriatic solution of tin. Thicken with 2 pounds of gum.

Printing of foulard pieces. The tables which serve for the impression of silk goods are so constructed as to receive them in their full breadth. Towards the part between the color or sieve tub and the table, the roller is mounted upon which the piece is wound. This roller, A B, *fig.* 309, has a groove, C, cut out parallel to its axis. Into this a bar is pressed, which fixes the end of the piece. The head, B, of the roller is pierced with several holes, in which an iron pin passes for stopping its rotation at any point, as is shown at B. At the other end of the table there is placed a comb, *fig.* 310, which is supported by pivots A B at its ends. The teeth of the comb are on a level with the cloth.

309



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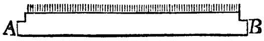


The piece is arranged for printing as follows:—It is unwound, and its end is brought upon the teeth of the comb, and made to pass into them by slight taps with a brush. It is now stretched, by turning round the roller, and fixing it by the pin-handle. After tracing the outline, the printing blocks are applied. Care should be taken, in the course of printing, always to fix the teeth of the comb in the middle line between two handkerchiefs. The operation of grounding-in is much facilitated by this plan of extension.

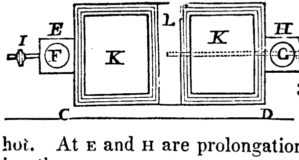
The pieces are washed in running water, and must be rapidly dried. The subsequent dressing is given by gum tragacanth: they are dried upon a stretching frame, and then folded up for the market.

III. *Mandarining of silk stuffs and chalys.*—This style of printing depends upon the property which nitric acid possesses of giving to silk and woollen stuffs a yellow color.

The first step is the scouring with a soap boil, as already described.

The designs are printed-on as also above described.

The swimming or color tub is usually double, and serves for two tables; instead of being placed, therefore, at the end of the table, it is put between two, and, consequently, behind the printer. It is formed of a copper chest, *fig.* 311, A B C D, in which steam may circulate, introduced by the pipe I; the excess being allowed to escape by the tube J, as also the water of condensation. The frame is placed in the hollow box K K. Between two such frames there is a plate of copper, L, which closes the box; it serves for laying the plates in order to keep them hot. At E and H are prolongations of the box, in which are set the vessels F G for holding the reserve paste.



311

Preparation of the reserve or resist paste.—Melt in a kettle 2½ lbs. of rosin; 1 lb. of suet; mix well, and put it into the basins F G′. By means of steam the reserve is kept melted, as well as the false color upon which the sieve floats. The piece of silk being laid upon the table, and the reserve spread upon the frame, the printer heats his block, which should be mounted with lead, if the pattern will permit, upon the little table L. He takes up the color from the frame, and transfers it instantly to the piece. He must strike the block lightly, and then lift it, lest, by its cooling, it might stick to the silk. When the table pattern is completed, he dusts it over with sand, and proceeds to another portion of the silk. The piece must not be

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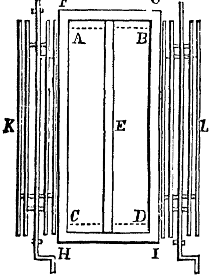
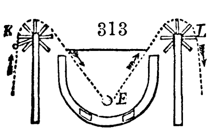
taken out of the stretch till it is quite dry, which requires usually 6 hours. Let us consider first the most common case, that of a white upon an orange ground. We shall afterwards describe the other styles, which may be obtained by this process. The piece, being printed and dry, must next be subjected to the *mandarining* operation.

312





The apparatus here employed consists of a sandstone trough A B C D, *fig*. 312. Upon the two sides, A C, B D, of this trough are fixed two wooden planks, pierced with a hole an inch from the bottom to receive the roller E, under which the piece passes. In this trough the acid mixture is put. That trough is put into a wooden or copper trough, F G H I. Into the latter, water is put, which is heated by means of steam, or a convenient furnace. Before and behind are placed two winces, or reels, K L; one serves to guide the piece in entering into the trough, and the other in its leaving it. The piece falls immediately into a stream of cold water, or, failing that, into a large back, containing a mixture of chalk and water. The two winces are moved by handles: the velocity is proportioned to the action of the acid. The wince L ought to be higher than K, to allow the acid to drain off. *Fig*. 313 shows a section of the apparatus.

The temperature of the acid mixture ought to be maintained between 95° and 100° F.; for if it be raised higher, the resist would run the risk of melting, and the impression would become irregular and blotty.

The proportions of the acid mixture are the following:—

1 gallon of water; and 1 gallon of nitric acid, of spec. grav. 1·288, which may be increased with the strength of the silk. It should be a little weaker for chalys. For the strong greens it may be 2 measures of acid of 1·288 to 1 measure of water. The duration of the passage through the acid should be 1 minute at most.

Mixture of orange color, and clearing away of the resist.—The goods, on coming out of the mandarining apparatus, are rinsed in running water; then boiled in soap water, quickened with a little soda, at the rate of 2 lbs. of the former and 4 oz. of the latter for a piece of 30 yards. They must be worked by the wince for half an hour. They are now rinsed in cold water, then passed through hot, again rinsed, and dried. I shall give some examples of the mode of manufacture, which is undoubtedly one of the most curious applications of chemical ingenuity.

1. *Orange ground with white figures.*

(1.) Print-on the fat reserve; (2.) mandarine; (3.) brighten the orange, and clear.

2. *Orange ground with blue figures.*

(1.) Dip in the indigo vat as for calico; (2.) print-on the fat resist to preserve the blue; (3.) mandarine; (4.) clear, and brighten the orange by the boil.

3. *Orange ground, with blue and white figures.*

(1.) Print-on the resist to preserve the white; (2.) dip in the vat, rinse, and dry; (3.) ground-in the fat resist to preserve the blue; (4.) mandarine; (5.) cleanse, and brighten.

4. *Full green ground, and white figures.*

(1.) Print-on the resist; (2.) mandarine, and rinse without drying; (3.) dip in the blue vat; (4.) cleanse, and brighten.

5. *Full green ground, and blue figures.*

(1.) Dip a pale blue, rinse, and dry; (2.) print-on the fat resist; (3.) mandarine, wash and dry; (4.) dip full blue; (5.) clean, and brighten.

6. *Full green ground, with white and blue figures.*

(1.) Print on the resist; (2.) dip a pale blue, and dry; (3.) ground-in the fat resist; (4.) mandarine and rinse; (5.) dip a full blue; (6.) clean, and brighten.

7. *Full green ground, with white, blue, and orange figures.*

(1.) Print-on the fat reserve; (2.) dip a pale blue, and dry; (3.) ground-in the reserve; (4.) mandarine, rinse, and dry; (5.) ground-in the reserve; (6.) dip a full blue; (7.) clean, and brighten.

If blue grounds with white figures be wanted, the resist must be applied, and then the goods must be dipped in the blue vat: the resist is afterwards removed by a boil in soap-water.

The above processes are applicable to chalys.

The property which nitric acid possesses of staining animal matters yellow, such as the skin, wool, and silk, is here applied to a very elegant purpose.

Of the bronze or solitaire style by mandarining.—The mandarining mixture is

1 gallon of nitric acid, of 1·17 spec. grav.; mixed with 3 pints of solution of nitrate of iron, of spec. grav. 1·65. If the quantity of nitrate of iron be increased, a darker tint will be obtained. The temperature of the mixture should be 94° F. The pieces, after mandarining, are let fall into water, and steeped for an hour.

In order to raise the bronze, and clear away the fat resist, the goods must be boiled in a bath of soap and soda, as described for orange.

1. *Bronze ground, with white figures.*

(1.) Print-on the fat resist; (2.) dip in the blue vat, and dry; (3.) pad in a decoction of logwood, of 4 lbs. per gallon; dry, taking care to turn over the selvages; (4.) mandarine, and steep in water for an hour; (5.) cleanse, and pass through soap.

2. *Bronze ground, with blue figures.*

(1.) Dip in the blue vat, and dry; (2.) print-on the fat resist; (3.) pad in the above decoction of logwood, and dry; (4.) mandarine, and steep an hour; (5.) cleanse, and brighten.

3. *Bronze ground, with white and blue.*

(1.) Print-on the fat resist; (2.) dip in the blue vat, and dry; (3.) ground-in the fat resist; (4.) pad in the logwood liquor, and dry; (5.) mandarine, and steep for an hour; (6.) cleanse, and give the brightening boil with soap.

This style of manufacture may be executed on chalys; and is capable of producing beautiful effects, which will in vain be sought for by other means.

With silks, advantage may be derived from various metallic solutions which possess the property of staining animal substances; among which are nitrate of silver, nitrate of mercury, and muriate of iron. The solutions of these salts may be thickened with gum, and printed-on.

An orange upon an indigo vat ground.—After the blue ground has been dyed, orange figures may be produced by printing-on the following discharge paste:—

1 gallon of water, made into a paste with 1 pound of starch; when cold, add to it from 16 to 24 ounces of nitric acid, of spec. grav. 1·288. After fixing the color by steam, the orange is brightened with a soap boil.

An orange upon a Prussian-blue ground.—The dye is first given by Prussian blue in the ordinary way, and then the following discharge is printed-on:—

A caustic ley being prepared, of 1·086 specific gravity, dissolve in a gallon of it 2 pounds of annotto, and thicken with 3 pounds and a quarter of gum. Two days after the impression of this paste, pass the goods through steam, and wash them in running water. With these two designs, the logwood and gall-black, formerly described, may be associated, to produce a rich effect.

To the preceding practical instructions for printing calicoes, silks, woollens, and mixed fabrics, made of the two latter, a few annotations may be added.

When a uniform color is to be applied to both sides of the cloth, the padding process is employed; but, when only one side is to be thus colored, diagonal lines are cut very closely to each other upon the cylinder, which transfer so much color from the trough to the cloth passed under it as to make the surface appear uniformly stained. This process is called *mattage* by the French. Mordants or topical dyes, to be applied in this way, should not be much thickened.

The *doubler* is the piece of felt or blanket stuff placed between the cloth to be printed, and the block printing-table, or the cylinders. It should be kept very clean; because, were it soiled with acetate of iron, it would spoil all the light shades made with acetate of alumina.

Filters for the color shop of a print-house are best made of wool, formed into a substantial conical cap by felting. A filter ought to be set apart for each different dye-stuff.

When the goods after dyeing are washed, by being held by the selvage, dipped, and shaken in a stream of water, the process is called *giving a list* by the French (*donner une lisière*). The piece is transferred alternately from one hand to another.

Stains. When we observe stains produced by mordants upon spots where no color is to come, we must, before dunging the goods, apply a little of the lime-juice, or tartaro-oxalic acid discharge paste, to the place. If, on the contrary, the stains are not perceived till after the maddering, we must then apply to it first a strong solution of chloride of lime with a pencil, next a solution of oxalic acid mixed with a little muriatic with another pencil, and immediately afterward wash with water. Every madder stain will be effaced by this means.

Rust stains are removeable by a mixture of oxalic and muriatic acids.

Indigo stains by the combined action of chloride of lime and muriatic acid.

Topical yellow stains, or yellow dyes, by the same combination.

Metallic greens and Scheele's green by the acid alone.

Chrome green, and Prussian blue. The blue may be taken out by a caustic alkali; after which the goods must be washed: the residuary rust stain may be removed by the mixture of oxalic and muriatic acids. The above methods refer to cotton and linen. The stains on silk and woollen stuffs should be removed before fixing the colors by the soap boil; which may generally be done by scratching with the finger, with the aid of a little water.

For a direct calico green, see oxyde of CHROME.

Mr. Hudson, of Gale, near Rochdale, obtained a patent, in December, 1834, for a mechanism which furnishes a continual and regular supply of color to the sieve or tear (*tire*, Fr.), into which the printer has to dip his block, for the purpose of receiving the color about to be transferred to the fabric in the operations of printing calicoes or paper hangings. The contrivance consists in a travelling endless web, moved by power, which, by passing progressively from the color vat over the diaphragm, brings forward continuously an equable supply of the colored paste for the workman's block.

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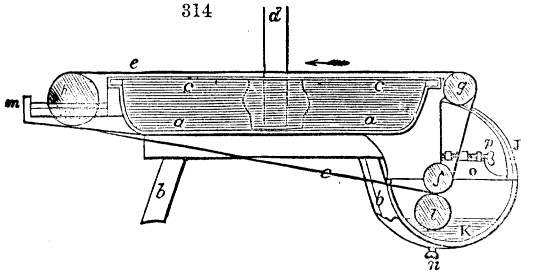

Fig. 314 represents the construction of this ingenious apparatus, shown partly in section. *a a* is a vessel of iron, supported upon wooden standards *b b*, over the upper surface of which vessel a sheet or diaphragm, *c c*, of oiled cloth, or other suitable elastic material, is distended and made fast at its edges by being bent over a flange, and packed or cemented to render the joints water-tight. A vertical pipe *d* is intended to conduct water to the interior of the vessel *a*, and, by a small elevation of the column, to create such upward pressure as shall give to the diaphragm a slight bulge like the swimming tub.

An endless web, *e e e*, passing over the surface of the diaphragm, is distended over three rollers, *f g h*, the lower of which, *f*, is in contact with the color-roller *i* in the color-trough K. On the axle of the roller *i* a pulley wheel is fixed, which allows the roller to be turned by a band from any first mover; or the roller may receive rotatory motion by a winch fixed on its axle. On this said axle there is also a toothed wheel, taking into a another toothed wheel on the axle of the roller *f*; hence, the rotation of the color-roller *i* in the one direction will cause the roller *f* to revolve in the opposite, and to carry forward the endless web *e e e*, over the elastic diaphragm, the web taking with it a stratum of color received from the roller *i*, evenly distributed over its surface, and ready for the printer to dip his block into.

The axles of the rollers *f* and *g* turn in stationary bearings; but the axle of *h* is mounted in sliding nuts, which may be moved by turning the screws *m*, for the purpose of tightening the endless web. The axle of the color-roller *i* turns in mortises, and may be raised by screws *n* in order to bring its surface into contact with the endless web. To prevent too great a quantity of color being taken up, the endless web passes through a long slit, or parallel aperture, in a frame *o*, which acts as a scraper or doctor, and is adjustable by a screw *p*, to regulate the quantity of color carried up. The contents of the vessel *a*, and of the color-trough *k*, may be discharged when required by a cock in the bottom of each. See PAPER HANGINGS, for the *Fondu* style.

The outside working gear of the four-colour calico printing machine, is shown in *fig.* 315., where A, A is a part of the two strong iron frames or cheeks in which the various rollers are mounted. They are bound together by the rods and bolts *a*, *a*, *a*. B is the large iron pressure cylinder, which rests with its gudgeons in bearings or bushes, which can be shifted up and down in slots of the side cheeks A, A. These bushes are suspended from powerful screws, *b*, which turn in brass nuts, made fast to the top of the frame A, as is plainly shown in the figure. These screws serve to counteract the strong pressure applied beneath that cylinder by the engraved cylinders D, E.

C, D, E, F, (see *fig.* 297.) are four printing cylinders, named in the order of their operation. They consist of strong tubes of copper or gun metal, forcibly thrust by a screw press upon the iron mandrels, round which, as shafts, they revolve. The first and last cylinders, C and F, are mounted in brass bearings, which may be shifted in horizontal slots of the frame A. The pressure roller B, against whose surface they bear with a very little obliquity downwards, may be nicely adjusted to that pressure by its elevating and depressing screws. By this means C and F can be adjusted to B with geometrical precision, and made to press it in truly opposite directions.

The bearings of the cylinders D and E are lodged also in slots of the frame A, which point obliquely upwards towards the centre of B. The pressure of these two print cylinders, C and F, is produced by two screws, *c* and *d*, which work in brass nuts made fast to the frame, and very visible in the figure. The framework in which these bearings and screws are placed has a curvilinear form, in order to permit the cylinders to be readily removed and replaced, and also to introduce a certain degree of elasticity. Hence the pressure applied to the cylinders C and F partakes of the nature of a spring,

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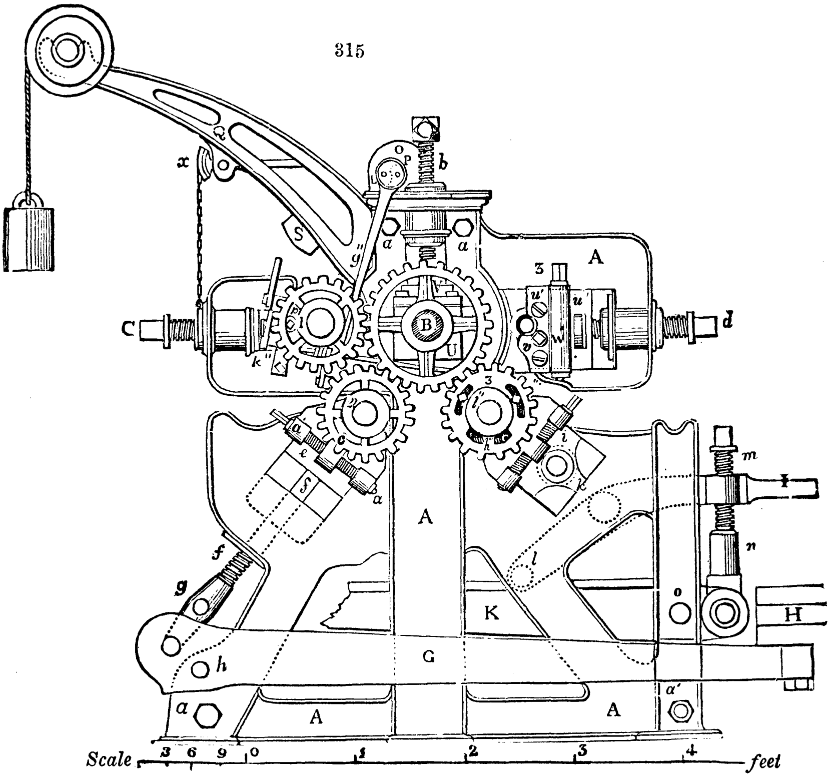

a circumstance essential to their working smoothly, notwithstanding the occasional inequalities in the thickness of the felt web and the calico.

The pressure upon the other two print cylinders, D and E, is produced by weights acting with levers against the bearings. The bearings of D are, at each of their ends, acted upon by cylindrical rods, which slide in long tubular bosses of the frame, and press with their nuts *g*, at their under end upon the smaller arms of two strong levers G, which lie on each side of the machine, and whose fulcrum is at *h* (in the lower corner at the left hand). The longer arms of these levers, G, are loaded with weights, H, whereby they are made to press up against the bearings of the roller D, with any desired degree of force, by screwing up the nut *g*, and hanging on the requisite weights.

The manner in which the cylinder E is pressed up against B is by a similar construction to that just described. With each of its bearings there is connected, by the link *k*, a curved lever I, whose fulcrum or centre of motion is at *o*. By turning, therefore, the screw *m*, the weight L, laid upon the end of the longer arm of the lever K (of which there is one on each side of the machine), may be made to act or not at pleasure upon the bearings of the cylinder E. The operation of this exquisite machine is minutely described in pp. 315, 316.

A patent was obtained in August, 1839, by Mr. J. C. Miller of Manchester, for certain improvements in printing calicoes, consisting of a modified mechanism, by which the same effect can be produced as by block printing.

Figs. 316, 317, 318, are several views of this machine, calculated to print two pieces, or two different patterns (on the same block) of calico, side by side, or four pieces, the carriage printing both ways, the intended device consisting of four colours to be printed from blocks.

Fig. 316. represents a side elevation, *fig.* 317. a front view, and *fig.* 318. a transverse section, taken nearly through the middle of the machine.

The side or main framing is shown at *a*, *a*, supporting the colour boxes *b*, *b*, *b*, with their *doctors;* the furnishing tables or beds, *c*, *c*, *c*, (substitutes for the sieves in ordinary block printing); the printing table, *d, d*; and the feeding, drying, and colouring rollers, *f, f, g, g, h, h.*

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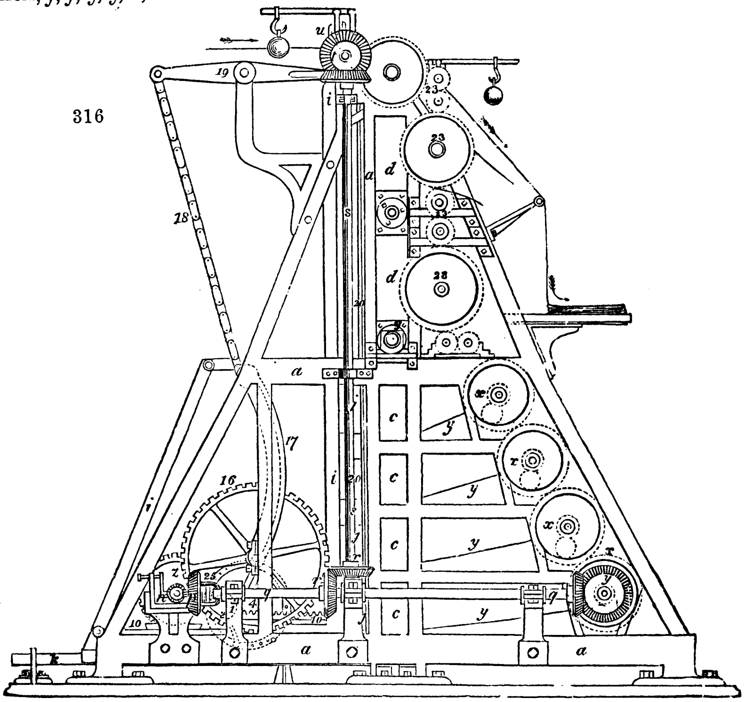

The machine is also provided with a carriage, *i, i,* for the printing blocks, *j, j, j.* This carriage, *i, i,* travels in and out at suitable intervals upon rails, *k, k,* attached to the main framing.

The operation of the machine is effected by passing a driving strap, *l,* round the driving pulley *m,* fixed at the extremity of the main driving shaft, *n, n.* At the other end of this shaft, the bevil pinion, *o,* is keyed, gearing at suitable intervals with the bevil wheel *p,*which is mounted upon the end of the cross shaft *q*; at about the middle of this shaft, the mitre wheels *r, r,* driving the upright shaft *s, s,* and mitre wheels *t, t,* above, actuate, by means of the spur pinions *u, u,* the feeding rollers *f, f,* and thus draw the pieces of goods into the machine.

Simultaneously with the progress of the cloth, the mitre wheels *v, v,* at the other end of the cross shaft *q,* drive the furnishing rollers *w, w, w,* by means of the spur gearing *x, x, x.* The furnishing rollers, revolving in their respective color-boxes, spread or apply the colors upon the travelling endless blankets, *y, y, y,* which pass round the top roller and the furnishing tables or beds, *c, c, c,* in order to supply the colors to the surfaces of the printing blocks, *j, j, j.* Either beds or the backs of the printing blocks may be made slightly elastic, to insure the perfect taking up of the colors.

Supposing the carriage, *i, i,* to be run out upon its railways, at the farthest point from the beds *c, c,* it is drawn inward toward the furnishing beds *c, c,* by means of the spur-wheel *x,* upon the driving-shaft *n,* taking into a small pinion, 1 (shown by dots in *fig.* 17), upon the shaft, 2. On the end of this shaft is also keyed the mangle pinion, 3, gearing in the mangle wheel, 4, which is keyed upon the end of the shaft, 5 This shaft drives the spur-wheel, 6, in gear with the pinion, 7, made fast to the shaft, (see *fig.* 19).

Upon either end of the shaft, 5, is a rack pinion, 9, taking into the horizontal rack 10, made fast to the carriage-frame, *i, i;* and thus the blocks *j, j,* are presented to the furnishing blankets *y, y, y,* and take a supply of colour ready for printing. The travelling-carriage and blocks now retire, by the agency of the mangle-wheel and pinion, 3 and 4, the pinion being fixed upon the end of the shaft, 2, and the wheel upon the other shaft in a line with the shaft 2. At this time another operation of the machine takes place.

Upon the reverse end of the shaft 5, is a pinion, 11, gearing with the spur-wheel 12; and by means of the spur gearing, 6 and 13, and counter-shaft, 14, the pinion 15 drives the spur-wheel, 16, which corresponds to the wheel, 12, on the other side of the machine. To one of these spur-wheels are attached by bolts two quadrant levers, 17, 17; and as these wheels revolve by means of the gearing just described, the levers, 17, 17, draw down the chains, 18, 18, actuate the levers, 19 and 20, and thus elevate the whole series of printing blocks in the parallel grooves, 21, 21; at the same time pressing or closing them into one mass or block by expanding the springs, 22, 22; and at the nest of the carriage caused at a proper interval by the agency of the mangle-wheel, the blocks are made to impress the patterns upon the surface of the goods at once, in four or more different colours, and in one, two, or more widths of cloth at one operation.

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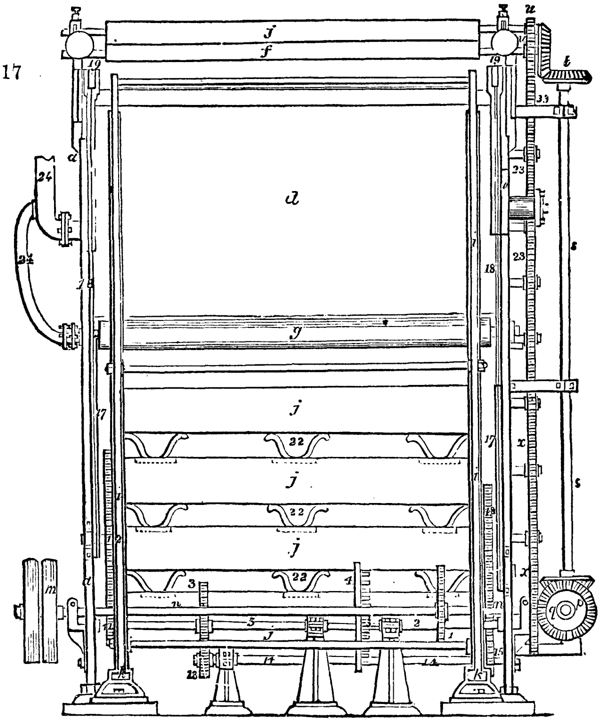

The cloth is now drawn forward for the space of the exact width of one of the blocks, or sketch of the design, by means of the spur-wheels and pinions, 23, 23, and passed around heated cylinders, *g g*, if necessary, and between the delivering rollers out of the machine. These operations are to be repeated by the continuous rotation of the main driving-shaft, until the printing is completed; the colours making a single advance upon the pattern at every presentation of the blocks, until the whole number of blocks has been presented to the same space or portion of the goods successively.

The steam pipes, 24, are to be in connection with the printing table and drying cylinders, in order to supply a degree of heat during the operation, which may be regulated at pleasure.

To give suitable intervals of rest and motion to the various parts of the driving-gear, an ordinary clutched box, 25 (shown in *fig.* 318.), and regulated by suitable stops fixed to the travelling carriage, is used for throwing the wheel *p*, in and out of gear with the pinion, *o;* this is to prevent clots of colour from being dragged upon the blocks or cloth.—*Newton's Journal*, xxi. C. S. p. 242.

General Observations.—The cotton of Pernambuco takes a more lively Turkey red dye than that of Georgia, and both are preferable to the Macedonian cotton. Goods woven of dead wool cannot be well dyed. Cloth of mixed cotton and wool yarns require a peculiar treatment from the calico printer. Blues do not take well on cotton.

Indigotine, carthamine, curcumine, oxide of iron, oxide of chrome, arseniuret of sulphur and of antimony, are all substantive colours, and need no mordant to fix them but they must be presented to the stuff in a soluble state, or rendered so by some solvent. This proposition is well illustrated in the indigo dye.

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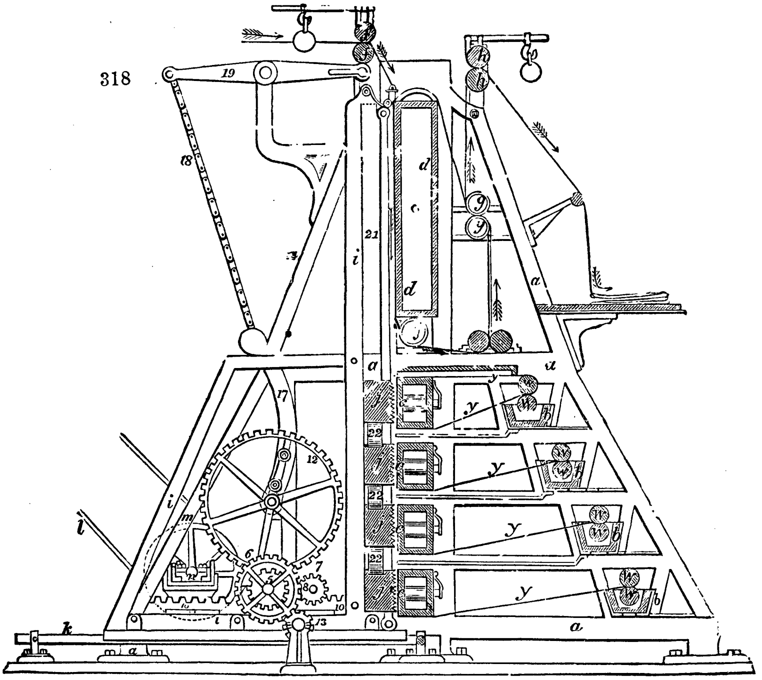

The ferruginous mordants for good dyes, applied by the plate, have almost always a little of a copper salt added to facilitate the peroxidation of the iron, and its combination with the stuff. The empyreumatical oil of pyrolignous acid has the power of retarding the oxidation, and preventing the corrosive action of the ferric acid upon the fibres. The arsenious acid is employed for the violets and lilacs; it combines with the iron-oxide in its normal state, and stops its peroxidation. The chlor-zinc used in the black mordant has no tinctorial operation, but it counteracts the tendency of the starch thickeners to coagulate. Sal-ammoniac and nitre are also in many cases of great service in mordants; as well as the muriates of potash and soda. When pyrolignite of iron alone is used, the dyes are not so rich as when some purer acetate of iron is added to it; to favour the more ready oxidizement of the metal, which should be always introduced into the stuff in the state of black oxide. The basic pyrophosphate of iron being soluble in alkalis makes thus an excellent mordant, especially with ammonia, which may be dyed immediately after impression. When a solution of sulphate of iron is mixed with one of pyrophosphate of soda, the whitish precipitate may be dissolved (after being washed) in water of ammonia. Such a mordant serves well for a madder bath, and also for many others.

Tin crystals (chloretin) dissolved in the sulphuric acid of Nordhausen to saturation, have at first the consistence of syrup, but become afterwards solid; and being kept out of contact of air, make the best of all tin mordants. For some purposes, however, the peroxide of tin is preferable.

Generalities of Calico Printing.—I. Of the colours fixed in the humid way, or in the water-bath, and with concourse of mordants; the simple *genera* are derived from the application of indigo, carthamus, curcuma, catechu, and the oxides of iron and chrome; the peroxides of manganese, and lead; with the sulphide of antimony.

1. From indigo, there are the following species:—

(1.) The blue vat or blue ground; such as pencil blue, china blue, blue of solid application. Indigo is reduced into a soluble state by grinding in the moist condition and mixing 100 parts of it with from 75 to 95 parts of green sulphate of iron, and 100 of quicklime, in the vat along with 8000 parts of water, and stirring vigorously from time to time. The vat is best heated by transmitting steam into it through pipes. By this means the indigo vat may be prepared for action in the course of 12 hours. The liquid should be transparent and of a fine yellow hue; and should have a coppery looking pellicle on its surface.

To insure complete oxidizement to the indigo in the substance of the stuff, it may be padded through a weak solution of sulphate of copper, mixed with a little boiled starch and glue. See Indigo.

Resist pastes for indigo may consist of solutions of the copper salts, which act on chemical principles by furnishing oxygen to the indigo and thus rendering it insoluble and incapable of entering the fibres of the stuff; or they are composed of pipe clay, sulphate of lead, and such articles as act mechanically. A resist paste with sulphate of zinc and alum answers well for brief immersions in the vat, and it washes easily away. The arseniates and phosphates are sometimes used along with the salts of copper to prevent the fixation of this metal reduced upon the cloth.

The following are some receipts for reserve pastes.

No. 1. For deep blues. In 9 quarts of water dissolve,
12 pounds of sulphate of copper
5 — acetate of copper
6 — nitrate of copper, at 15° B.
5 — gum arabic
2 — pipe clay; the latter two being thickeners.
No. 2. In 9 quarts of water dissolve,
8 pounds of sulphate of copper
4 — acetate of copper
6¾ — nitrate of copper, at 55° B. thickened with
4 — gum arabic
8 — pipe clay
No. 3. For cravats. In 9 quarts of water dissolve
8 pounds of sulphate of copper
4 — acetate of copper
4 — nitrate of copper, at 55° B., thickened with
4 — of gum arabic
8 — of pipe clay.

In other formulæ, a little alum is used; in others, verdigris dissolved in vinegar is added to the mixture; in some a little cream of tartar is introduced, also a very small quantity of sulphuric acid for handkerchiefs to be printed on both sides. In 9 quarts of water, 3 pounds of sulphate of copper, ½ pound acetate, to be thickened with ⅓ pound of starch and 7 pounds of gum, 6½ pounds of pipe clay; the whole being coloured with 1 pound of acetate of indigo.

By another formula a resist paste is made by dissolving in 8 pints of water, 20 pounds of sulphate of zinc, incorporated with

4½ pounds of pipe clay
5 — of soft soap
1½ — of lard
1½ — olive oil
½ — oil of turpentine
12 — of mucilage at 2 pounds per quart.

All the above pastes should not be thicker than what is absolutely necessary, and the cloth to be printed should be highly calendered; in printing with blocks the workmen should strike them with their hand and not with a mallet. It is advisable to dip the frame with its stretched piece of cloth in milk of lime before plunging it in the vat; in which it should receive 4 or more immersions, with airing intervals for the oxidizement of the indigo.

Pencil blue, as applied by hand.—To 35 quarts of water, add 12 pounds of carbonate of potash, 10 of quicklime, 10 of indigo, 12 of realgar. This mixture is to be boiled for 2 hours, then poured into a tub to settle, when the clear part is to be thickened with gum arabic in the proportion of 1 pound to 4. The insoluble matter is treated with a fresh quantity of water, and boiled repeatedly till it be quite exhausted, and it then serves ulterior purposes. For this prescription may be substituted with advantage a solution of the realgar in caustic potash, so as to avoid the annoyance introduced by the lime. This pencil blue has been of late successfully applied by the cylinder press, working in an atmosphere of coal gas, to prevent the oxidizement by the atmospheric oxygen, till the web was all uniformly printed.

Of the styles of colour derived from Carthamus (*safflower*).—Safflower being washed in pure water, is to be immersed in solution of carbonate of soda, of which the weight

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should in no case exceed that of the safflower; for an excess of it, or too long digestion or at too high a temperature, must be avoided. The alkaline compound, called carthamate of soda, is to be poured into an oval tub, having a discharge pipe at its bottom and two supports at each end of the tub, for bearing the pivots of the reel round which the cloth is coiled, and which is turned by means of a handle. The liquid being slightly super-saturated with lemon juice, passes from orange to a lively pink hue, and becoming *carthamine* is ready to be deposited upon the cloth as it revolves in the tub. Silks, which have been sulphured, are to be previously passed through a soda bath. But brighter colours are obtained upon cotton.

Of the styles of colour derived from curcuma (*turmeric*). This drug is employed chiefly to modify the tints produced by other dyes: into a decoction of it any kind of goods, cotton, silk, wool, or linen, being immersed, take a yellow stain without any mordant. This substance has been associated with Brazil-wood for printing certain kinds of silk handkerchiefs with a mordant of iron and alumina.

The colours derived from annotto.—To dye cloth with annotto, an alkaline decoction is to be made of it, along with a solution of dextrine, into which the cloth is to be plunged. It needs no mordant, and affords an orange brown dye, after the alkali has been neutralized by an acid bath. A solution of peroxide of tin brightens the dye.

Of the styles of printing by means of catechu.—1. This dye stuff, combined with the blue vat, produces very fine blacks. Catechu is prepared for dyeing by dissolving in 9 quarts of water, 7½ pounds of it along with 1 pound of acetate of copper, 2 pounds of sal ammoniac, and 10 pounds of gum arabic.

2. To 9 quarts of pyrolignous acid, put three pounds of catechu in fine powder, which has been steeped in 12 quarts of water. The mixture is to be evaporated at a gentle heat, till it be reduced by one tenth, allowed to settle, and set aside for use.

To 9 quarts of the above prepared catechu, there are to be added 2½ pounds of sal ammoniac, 4 of gum arabic, 5 of pipe clay, and 1 of nitrate of copper.

Introducing into this preparation salts which promote oxidation, the shade may be modified, and other colours produced. Thus, in adding to 6 quarts of the above 6 quarts of acetate of protoxide of iron, at 12° B. and 9 pounds of gum arabic; or adding to 9 quarts of the above catechu preparation, 14 quarts of water, 18 of mucilage, containing 2 pounds of gum per quart, and 9 of protacetate of iron of 9° B.

This colour, which is employed for cylinder printing, may be extensively modified; the acetate of iron may be replaced by a mixture of acetate and sulphate, or even by the nitrate, if the proportions of the other soluble matters be changed. If the preparations are to be rendered more oxidable, a little corrosive sublimate or chloride of tin may be added.

Catechu with manganese (acetate of) either alone, or with acetate of copper, forms an excellent dye. Catechu is also united with alkalis, and with sulphate of chrome, or tartaro-acetate of copper; chlor-calcium and acetate of lime are likewise introduced into the formulæ by some printers, for the purpose of keeping the mordants moist, as the colours of catechu are thereby rendered richer.

After having exposed the goods printed with one or other of the mixtures for some days to a humid atmosphere, from a hazel nut tint they become of a marron hue. The colours are then fixed by steaming, or by means of a chromate or of lime, as a milk or water.

Alkaline catechu gives a brown red impression. 9 quarts of the decoction of catechu, at ¼ pound per quart, are to be thickened with 2¼ pounds of flour, and when it is boiled, 4½ quarts of solution of caustic soda at a density of 10° B. By varying the proportion of catechu without changing the ratios which exist among the other substances, stronger or fainter shades may be obtained, but only after several days' digestion. Lime is used for fixing such colours.

Of the colours derived from the application of the peroxide of iron.—One of the ferruginous preparations here employed is the nitro-sulphate of iron (protoxide). It is made by adding to 10 quarts of nitric acid, about three times its weight of sulphate of iron by very slow degrees in a large vitriol bottle; and by the mutual action of these ingredients a portion of ammonia is formed. Six days are required to complete this compound. Towards the conclusion the sulphate must be added very slowly, otherwise frothing will ensue in the thickening liquor. It is liquid at the temperature of 59° Fahr. and has a density of 56° to 57° B. When cooled below that point it has a tendency to crystallize. It should always be diluted to a strength of from 18° to 22° B. before being used. To dye with this preparation it is to be diluted to the desired degree, and put into the padding trough, where it serves to impregnate the goods uniformly. They are then transferred to the stove, where they are to be dried, but not to hardness, for fear of corroding the fibres by the red oxide of iron; they are next passed through a peculiar padding machine containing a weak solution of carbonate of soda mixed with a little quicklime. In proportion as the cloth is passed through the bath, and its alkaline matter gets neutralized, it must be refreshed with fresh solution of soda. The cloth may be supplied by a soap-bath; and lastly by the dash-wheel. If the iron orange tint is not sufficiently deep by one operation, it may be increased by another, and also rendered more uniform. A mixture of red muriate of iron and sal ammonia gives a good iron dye, and with perfect safety; or one of red sulphate and sal ammoniac. Goods padded in iron liquor, dried, and then padded in a solution of chlorine containing a little free-lime, acquire a good *rust* ground. The following prescriptions serve as resist pastes for these dyes. In 9 quarts of hot water dissolve 5 lbs. of the biarsenate of potash, and add to the solution as much carbonate of potash as to give it a slight alkaline reaction. Dividing this liquor into two equal parts, there is to be incorporated with the first, 10 lbs. of pipe-clay, and to be dissolved in the second 4½ lbs. of gum senegal, with ¾ of a pound of soft soap; the two are to be united. This resist is to a certain degree of a mechanical quality, for the ferruginous preparation cannot touch it, without setting the fat acid of the soap at liberty and preventing the entrance of the liquor into the pores of the web.

White resists on rust grounds are also made with a mixture of tartaric and oxalic acids; as also of lime juice. When the iron oxide is fixed, as in the genus avanturine, muriate of tin is a preferable discharge; as for example:

In 9 quarts of water diffuse 3¾ lbs. of flour, 1 lb. of starch, and boil into a paste; and add to 2 lbs. of this paste, 2 lbs. of acid muriate of tin at 65° B. (solution of salt of tin in muriatic acid.) This for printing with the block. For printing on the discharge paste by the cylinder, to 2 lbs. of the paste are to be added 4 lbs. of the acid muriate of tin at 65° B. In these preparations the combined action of the muriatic acid and muriate of tin is sufficient to displace the oxide of iron; but the paste must not be left long exposed to the air, otherwise the iron may become fixed by peroxidizement. White discharge upon *chamois* (a faint rust colour) is produced by 11 lbs. of gum arabic, 2½ lbs. of oxalic acid, 2 lbs. of tartaric acid, ½ lb. of oil of vitriol. After applying this discharge the goods should not be exposed to a high heat to dry them. The first of these two receipts tends to crystallize, the second to deliquesce. It deserves to be remarked, that when soda is employed to precipitate rust of iron upon goods, the tint is much deeper than it is by lime.

Of the colours produced by the oxide of chrome.—A preparation for this purpose is made by boiling together 2 lbs. of bichromate of potash, and 4 lbs. of muriatic acid. The muriatic acid excess is to be evaporated off. For obtaining deeper shades, arsenic acid is introduced in determinate proportions; as for example:

To 9 quarts of water, there are added 9 lbs. of bichromate of potash, 12 of arsenious acid, and 20 or 22 lbs. of muriatic acid, in order to destroy all the chromic acid, and that the chlorine set at liberty in contact with the water and the arsenious acid may transform the last into arsenic acid by the oxygen of the decomposed water. When the reaction has ceased, a fine green liquor results, which is to be evaporated to the density of 60° or 65° B. to dissipate the free acid; care should be taken to get rid of the acid excess either by a regulated heat or by soda. Many pieces of calico are dyed a fine green by the oxide of chrome, and are very fast.

The solution of muriate of chrome, just described, at a density of 45° B., is to be thickened slightly with gum, poured into a padding machine, then dried carefully to aid the fixation of the colour, and finally passed through a weak bath of soda: to complete the deposition of the oxide of chrome, ammonia may be substituted for the carbonate of soda. The colours thus produced are pale green, or grey, but may be deepened by passing the cloth through a weak bath of sulphate of copper; it may be deepened also by mixing with arsenic acid, and after some days' repose, precipitating the arseniate of chrome on the stuff by passing it through a bath of carbonate of soda.

Of the simple genera derived from oxide of manganese.—This colour is generally known by the name of *solitaire bistre*, and sometimes turks-head. By impregnating the cloth with a neutral solution of acetate of manganese, then precipitating the oxide with an alkali, exposing the goods to the air to favour the oxidation, or passing them through a bath of chlorite of lime, the process of the manganese dye may be executed. After passing the goods through the manganese bath over 8 rollers, to secure uniformity of impression, they should be dried immediately in a stove. The dye-bath should contain a small quantity of mucilage of gum arabic. The alkali for precipitating the oxide of manganese in the padding machine should be caustic, strong, and heated by a steam pipe to the boiling point. The strength of the alkaline solution should in all cases be 14° B.: and for some purposes even 22° B. This alkaline strength is requisite to seize the fibre the instant of the tissue entering the alkaline bath, and to force, by the contraction which it causes, the oxide of manganese to remain within it till the oxidation is completed. It is obvious that the bath must be kept up by fresh alkali. The two last cylinders of the frame should be heavily loaded, so as to render the goods as dry as possible. A passage through solution of chlorine is in general advantageous to complete the

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oxidation of the manganese. A more economical process would be to add an equivalent of sal ammoniac to an equivalent of chlormanganese, and to make the solution alkaline with a little ammonia. The goods padded in this liquor might be dried without risk of injury, and be then finished in the baths, first, of milk of lime, and next of chlorine: or at once in a mixture of the two.

The shades with a foundation of manganese are often modified in various ways; as by adding to the mixture a certain quantity of acetate of lead, whence results chlorlead; while in passing into the solution of chlorlime, the lead is transformed into peroxide, whose brownish yellow added to the tint of the manganese produces a yellowish cast and a velvety aspect. Sometimes some salts of iron are added, which decomposed and peroxidized along with the salts of manganese give shades which resemble aventurine, the more closely the larger the proportion of iron.

Prussian blue.—Its white discharge is effected upon calico, by preparing a rust ground of a proper tint for producing with acidulated ferrocyanure of potash the desired blue shade. Into either the mordant or into the ferrocyanide put the quantity of muriate of tin necessary to give the blue its purest tint. The discharge is performed usually at two operations, by the first the ferrocyanure is decomposed by a powerful base (potash), which forms a yellow cyanure, and liberates the iron oxide; by the second, we remove the iron, by the intervention of an acid. But the success of this second operation depends on the energy of the first, and especially upon the washings which follow it, and which ought to have carried off the whole of the ferrocyanure; otherwise the presence of the acid would regenerate the blue upon the points which should remain clear of it. The pieces, after being dried and calendered, receive an impression with caustic-potash ley (thickened with gum), and which in every case should mark at least 14° B., in order to make the texture contract or shrink suitably, and furnish a precise or sharp print. It is then to be rinsed and washed in the dash-wheel so as to clear away every thing but the oxide of iron from the cloth upon all points touched by the alkali. The piece is then immersed in water acidulated with muriatic or sulphuric acid, till the oxide of iron has entirely disappeared. By adding to the potash a little tartrate of potash, the oxide of iron from the Prussian blue enters into combination with the tartaric acid, and goes off in a great measure with the subsequent washings.

This style may also be executed upon silk and woollen goods, but great precaution must be used to avoid injuring the texture by the strong alkaline ley. Silk handkerchiefs are first passed for about thirty minutes through a bath of nitrate of iron of 4° B., then through running water, next through the dash-wheels. They are next put in a bath of clear and cold lime water, in order to decompose the salt of iron, and to fix the oxide upon the stuff. It is now rinsed, and sent through the dash-wheel before proceeding to dye it; which is done by passing it through a tub sharpened with a little sulphuric acid, and containing a small quantity of ferrocyanure of potash. After working the cloth fifteen or twenty minutes in this bath, a little more acid and ferrocyanure are introduced, and the passage of the cloth is resumed during fifteen minutes more, which time is usually sufficient to produce the desired tint. It might be better to decompose previously in a separate vessel the ferrocyanure by adding to one equivalent of it in solution two equivalents of sulphuric acid. The mixture of sulphate of potash and ferrocyanic acid thence resulting, should be poured by degrees into the dyeing bath, till the due tint is produced, or the oxide of iron on the cloth becomes saturated. When the ground has been thus dyed, the discharge-printing may be proceeded with as already directed. Muriate of tin may sometimes be substituted for acid, for acidifying the ferrocyanure of potash in the act of dyeing.

By substituting oxide of copper for oxide of iron, a crimson colour is obtained with the ferrocyanure.

Saxon blue; solution of indigo in sulphuric acid.

This blue dye is given by passing the cloth mordanted with base of alumina through the indigo solution of a proper degree of strength. It enters also as an ingredient in certain pistachio green dyes.

The genera of styles derived from madder are numerous.

There are, 1. Plain grounds upon ordinary cloth; albuminous mordant.
2. do. ; iron mordant,
3. do. ; mordant of alumina and iron,
4. do. ; mordant of chrome,
5. Plain printing; white reserve with mordants of alumina, iron, or chrome,
6. do. white discharge upon common madder dye.
7. do. white discharge on oiled cloth, with madder dye mordants of iron (violet and lilac) upon the cylinder.

White ground; printing with alumina mordant for red and pink upon the cylinder

White ground; printing on mordants of alumina and iron.

White ground; printing on mordants; for red, violet, puce, black; a binary, threefold, and fourfold union of these colours.

White ground; printing on mordants, for red, violet, or puce; separate or combined; by the block or Perrotine. Plain ground upon oiled mordanted cloth: with alumina or iron. Turkey red, or violet oiled.

White ground; printing with mordant of iron and alumina upon oiled cloth.

The colours obtained directly by madder are *red* and its gradations, *pale red* and *pink*, which have always an aluminous mordant for their base; *black* and its gradations: *deep violet*, *light violet*, and *lilac*, of which the base is pyrolignite of iron, or the common acetate; red and deep puce, whose mordant is a mixture of aluminous and iron liquors; lastly, the *ventre de biche* fixed by means of the oxide of chrome.

In every print wort, three principal mordants are prepared beforehand in a certain state of concentration, which are diluted when wanted with water, but more frequently with gum-water, and vinegar.

A. Mordant for red is made with 100 quarts of boiling water in which are dissolved 150 pounds of alum; and then 150 pounds of pyrolignite of lead added.

B. Mordant for red,
100 quarts of water, in which are dissolved,
70 pounds of alum, 48 pounds of acetate or pyrolignite of lead, 2½ pounds of carbonate of soda (crystals), 4 pounds of muriate of soda.

C. Mordant for red.
In 100 quarts of boiling water are to be dissolved,
66 pounds of alum; and then to be added,
56 pounds of pyrolignite of lime, and
5 pounds of soda carbonate in crystals.

Red Mordant.

To 66 quarts of decoction of logwood, add 100 quarts of boiling water; and dissolve in this mixture 67 pounds of alum, 56 pounds of pyrolignite of lead, and 6 pounds of soda:

Other mordants are made of like quantity in which decoction of quercitron is put along with chlorzinc; some into which an admixture of chalk is made, others with an admixture of acetate of lead, and some chalk.

The blacks are made by strong mordants, with some salt of copper.

Cochineal is used much in the same way as for the madder printing and discharges, and the mordants are much the same; Brazil wood printing is of like nature: as also logwood dyes. The styles of printing derived from mixed colours are innumerable; but all proceed on the principles already laid down.

Calico Printing by Steam.—All textile fibres do not attract colouring matters to them with an equal power, but they may be rendered capable of acting with more or less force by adventitious aids, of which the use of steam conjoined with the salts or oxides of tin forms two of the most remarkable. The muriate or chloride of tin is decomposed by the action of water into muriatic acid and oxide of tin, the first of which is expelled by the heat of steam, or it may be neutralized by the intervention of a saturating substance; while the second is never set at liberty in presence of cloth without making such a body with it, as to resist all the means of discharge employed for the removal of the other substances, and without fixing at the same time on the fibres the colouring matter previously mixed with it. The same reasoning may be applied to the muriate of alumina. Oxalic acid fulfils at once the functions of these two saline compounds. It is an agent employed to remove the oxides or the mordants; and this application is based upon the affinity which it has for alumina and iron. When deposited upon a mordanted cloth, it may either make the whole of the oxide disappear, if used in sufficient quantity, or it may restore it in whole or in part eventually, if the contact be prolonged at the ordinary temperature, or immediately when exposed to steam. It is thereby easy to explain certain phenomena, since by its energetically dissolving the oxides, it preserves them in solution during the whole period of printing them, and then quits them under the influence of a steam heat; and leaves them on the cloth in all their properties when alone. It is to this peculiar property of the oxalic acid that we must ascribe the solidity of certain topical blacks, for which it has been long employed.

The tartrates and tartaric acid concur also to the same end; but the affinity of this acid for the bases, and the force with which it masks them, render its application more limited than the oxalic acid. It is useful for effecting displacements, and for preserving oxides in solution, so as to insure homogeneity to colours.

Acetic acid enters also as an ingredient into steam printing; possessing a solvent power different from the other acids, and being applicable in a state of concentration without corroding the tissues, it is applied in circumstances where substances of a more or less resinous nature need to be kept in solution in order to being printed on; whilst quitting under the influence of heat the bases with which it is associated, it allows them to contract an intimate union with the stuffs. The salts of copper and chromate of potash are employed to perform the oxidizing power of the absent air.

The colours fixable by steam, after having been suitably thickened, are to be printed with the nicety appropriate to each, and the goods covered with them should be previously exposed for some time to a damp atmosphere. In the steaming process, the goods are coiled round a perforated hollow cylinder charged with steam by a central pipe, or they are exposed on frames in single pieces without mutual contact in wooden cases filled with steam. Care must be had to prevent the dropping down of condensed steam upon the goods. When rolled up in a cylindrical form, they are wrapped in blanket stuff. Of late years contrivances have been made to keep the cloth moving in the steam so as to receive the equal benefit of its action. A great variety of other forms of this steam-bath are in use, according to the fancy of the operators. But in all cases there should be a redundance of highly elastic steam, of vesicular quality, which is secured by causing it to bubble up through a stratum of water lying on the bottom of the case.

CALOMEL. (*Chlorure de Mercure*, Fr.; *Versusstes Quecksilber*, Germ.) The mild protochloride of mercury. The manufacture of this substance upon the great scale may be performed in two ways. The cheapest and most direct consists in mixing 1⅛ part of pure quicksilver with 1 part of pure nitric acid, of sp. grav. from 1·2 to 1·25; and in digesting the mixture till no more metal can be dissolved, or till the liquid has assumed a yellow colour. At the same time a solution of 1 part of common salt is made in 32 parts of distilled water, to which a little muriatic acid is added: and, when heated to nearly the boiling point, it is mixed with the mercurial solution. The two salts exchange bases, and a protochloride of mercury precipitates in a white powder, which after being digested for some time in the acidulous supernatant liquor, is to be washed with the greatest care in boiling water. The circumstances which may injure the process are the following:—1. When less mercury is employed than the acid can dissolve, there is formed a deuto-nitrate of mercury, which forms some corrosive sublimate with the common salt, and causes a proportional defalcation of calomel. 2. If the liquors are perfectly neutral at the moment of mixing them, some subnitrate of mercury is thrown down, which cannot be removed by washing, and which gives a noxious contamination to the bland calomel. The acid prescribed in the above formula obviates this danger.

The second manner of manufacturing calomel is to grind very carefully 4 parts of corrosive sublimate (bichloride of mercury) with 3 parts of quicksilver, adding a little water or spirits to repress the noxious dust during the trituration. The mass is then introduced into a glass globe, and sublimed at a temperature gradually raised. The quicksilver combines with the deutochloride, and converts it into the protochloride, or calomel. The following formula, upon the same principle, was recommended to the chemical manufacturer in Brande's Journal, for July, 1818:—

"Prepare an oxysulphate of mercury, by boiling 25 pounds of mercury with 35 pounds of sulphuric acid to dryness. Triturate 31 pounds of this dry salt with 20 pounds 4 ounces of mercury, until the globules disappear, and then add 17 pounds of common salt. The whole is to be thoroughly mixed, and sublimed in earthen vessels. Between 46 and 48 pounds of pure calomel are thus produced: it is to be washed and levigated in the usual way." The above is the process used at Apothecaries' Hall, London. The oxysulphate is made in an iron pot; and the sublimation is performed in earthen vessels. The crystalline crust or cake of calomel should be separated from the accompanying grey powder, which is nearest the glass, and consists of mercury mixed with corrosive sublimate.

An ingenious modification of the latter process, for which a patent, now expired, was obtained by Mr. Jewell, consists in conducting the sublimed vapours over an extensive surface of water contained in a covered cistern. The calomel thus obtained is a superior article, in an impalpable powder, propitious to its medical efficacy.

The presence of corrosive sublimate in calomel is easily detected by digesting alcohol upon it, and testing the decanted alcohol with a drop of caustic potash, when the characteristic brick-coloured precipitate will fall, if any of the poisonous salt be present. To detect subnitrate of mercury in calomel, digest dilute nitric acid on it, and test the acid with potash, when a precipitate will fall in case of that contamination. As it is a medicine so extensively administered to children at a very tender age, its purity ought to be scrupulously watched.

118 parts of calomel contain 100 of quicksilver

A patent was obtained in September, 1841, by Anthony Todd Thomson, M. D.,

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for an improved method of manufacturing calomel and corrosive sublimate, as follows:—

This invention consists in combining chlorine in the state of gas with the vapour of mercury or quicksilver, in order to produce calomel and corrosive sublimate.

The apparatus employed consists of a glass, earthenware, or other suitable vessel, mounted in brick-work, and communicating at one end with a large air-tight chamber, and at the other end, by means of a bent tube, with an alembic, such as is generally used in generating chlorine gas. The alembic is charged with a mixture of common salt, binoxide of manganese and sulphuric acid, or of binoxide of manganese and muriatic acid, in order to produce chlorine gas.

The mode of operating with this apparatus is as follows:—A quantity of mercury or quicksilver is placed in the glass vessel, and the temperature of the same is raised to between 350° and 660° Fahr., by means of an open fire beneath. The chlorine gas, as it is generated, passes from the alembic through the bent tube into the glass vessel, and there combining with the vapour of the mercury, forms either corrosive sublimate or calomel, according to the quantity of chlorine gas employed.

The product is found at the bottom of the air-tight chamber, and may be removed from the same through a door, when the operation is finished.

According to the patent of Mr. Josiah Jewell, the vapour of calomel was to be transmitted into a vessel containing water, in order to condense it at once into an impalpable powder. But this process was beset with many difficulties. The vapour of the calomel was afterwards introduced into a large receiver, into which steam was simultaneously admitted; but this plan has also been found to be precarious in the execution. The best way is to sublime the calomel into a very large chamber from an iron pot, in the same way as the flowers of sulphur are formed. The great body of cool air serves to cause the precipitation of the calomel in a finely comminuted state. It is afterwards washed with water, till this is no longer coloured by sulphuretted hydrogen.

CALORIC. The chemical name of the power or matter of heat.

CALORIFERE OF WATER. (*Calorifère d'eau*, Fr.; *Wasser-Heitzung*, Germ.) In the *Dictionnaire Technologique*, vol. iv., published in 1823, we find the following description of this apparatus, of late years so much employed in Great Britain for heating conservatories, &c., by hot water circulating in pipes:—

"This mode of heating is analogous to that by stove-pipes: it is effected by the circulation of water, which, like air, is a bad conductor, but may serve as a carrier of caloric by its mobility. We may readily form an idea of the apparatus which has been employed for this purpose. We adapt to the upper part of either a close kettle, or of an ordinary cylindric boiler A, *fig.* 319, a tube B, which rises to a certain height, then descends, making several sinuosities with a gentle slope till it reaches the level of the bottom of the boiler, to whose lowest part, as that which is least heated, it is fitted at C. At the highest point of the tube F we adapt a vertical pipe, destined to serve as an outlet to the steam which may be formed if the temperature be too much raised: it serves also for the escape of the air expelled from the water by the heat: and it permits the boiler to be replenished from time to time as the water is dissipated by evaporation; lastly, it is a tube of safety.

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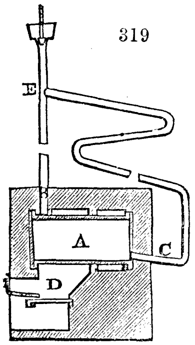

"The apparatus being thus arranged, and all the tubes as well as the boiler filled with water, if we kindle fire in the grate D, the first portions of water heated, having become specifically lighter, will tend to rise: they will actually mount into the upper part of the boiler, and, of course, enter the tube B F: at the same time an equivalent quantity of water will re-enter the boiler by the other extremity C of the tube. We perceive that these simultaneous movements will determine a circulation in the whole mass of the liquid, which will continue as long as heat is generated in the fireplace; and if we suppose that the tubes, throughout their different windings, are applied against the walls of a chamber, or a stove-room, the air will get warmed by contact with the hot surfaces; and we may accelerate the warming by multiplying these contacts in the mode indicated.

"This *calorifère* cannot be employed so usefully as those with heated air, when it is wished to heat large apartments. In fact, the passage of heat through metallic plates is in the ratio of the difference of temperature and quantity of the heating surfaces. In the present case, the temperature of the water, without pressure, in the tubes, must be always under 100° C. (212°, F.), even in those points where it is most heated, and less still in all the other points, while the temperature of the flues in *air stoves*, heated directly by the products of combustion, may be greatly higher. In these stoves, also, the pipes may without inconvenience have a large diameter, and present consequently a large heating surface; whereas, with the water *calorifère*, the pressure exercised by liquid upon the sides of the tubes being in the ratio of the surfaces, we are obliged, in order to avoid too great pressure, to employ a multitude of small tubes, which is expensive. Lastly, if the hot-water circulation is to be carried high, as may be often necessary in lofty buildings, the pressure resulting from the great elevation would call for proportional thickness in the tubes and the boiler: for these reasons, and others which we shall state in treating of heating by steam, it appears that water cannot be advantageously substituted for air or steam in the applications above stated; yet this mode of heating presents very decided advantages where it is useful to raise the temperature a small number of degrees in a uniform manner." See INCUBATION, ARTIFICIAL.

"M. Bonnemain applied, with much success, these ingenious processes of heating by the circulation of water, to maintain a very equal temperature in hot-houses (*serres-chaudes*), in stoves adapted to artificial incubation, and in preserving or quickening vegetation within hot-houses, or outside of their walls, during seasons unpropitious to horticulture.

"Since the capacity of water for heat is very great, if the mass of it in a circulation-apparatus be very considerable, and the circulation be accelerated by proper arrangements, as by cooling the descending tube exterior to the stove-room, we may easily obtain by such means a moderately high and uniform temperature, provided the heat generated in the fire-place be tolerably regular We may easily secure this essential point by the aid of the *fire-regulator*, an instrument invented by M. Bonnemain, and which is described under the article INCUBATION, because there its use seems to be indispensable."

From the above quotation, and, more especially, from the evidence adduced in the article INCUBATION, we see how little claim the Marquis de Chabannes, or any of his followers, can have to invention in their arrangements for heating apartments by the calorific motions of the particles of water, enclosed in pipes of any kind.

CALOTYPE is the name given by Mr. Fox Talbot to the art invented by him, of making pictures on paper or other such surfaces by the agency of light. It is merely a modified kind of *photography*. The processs is as follows:—Dissolve 100 grains of crystallized nitrate of silver in 6 ounces of distilled water, and brush over the paper (Whatman's sized post answers well) with a soft brush on one side only with this solution, and mark the side. When nearly dry, dip it into the solution of iodide of potassium (for only a few minutes), containing 500 grains of that salt dissolved in a pint of water. As soon as the paper is completely imbued with this solution, it should be immediately washed in distilled water, drained, and hung up to dry. This paper is to be kept for subsequent use in a portfolio, and carefully secluded from light.

Next dissolve 100 grains of silver-nitrate in 2 ounces of distilled water, and add to the solution one-sixth of its volume of strong acetic acid. Keep this solution in the dark. Make a saturated solution of gallic acid in distilled water. When it is required to make a calotype picture, the two liquids last described are to be mixed in equal quantities, but only so much as is needed for the operation. With this gallo-nitrate of silver a sheet of the silver iodide paper is to be washed over upon its marked side with a soft brush, an operation to be performed by candle-light. After half a minute, the paper being dipped in water, and dried lightly by pressure between folds of blotting paper, becomes so exceedingly sensitive to light as to take a pictorial impression in the camera in a space varying from one second to five minutes, according to the brightness of illumination. The camera should be mounted with a meniscus lens, in an adjustable tube, so as to throw the image of the object to be calotyped upon a vertical plate of roughened glass, in the posterior side or wall of the wooden box. Whenever the focus is correctly adjusted, the glass is withdrawn, and replaced by sliding in a groove a frame with the prepared sheet of paper fixed flat upon it, the prepared side towards the lens, but screened from light by a card or thin board. The telescope, which has been invented for calotype purposes, by Dr. Petzval and M. Voigtlander, of Vienna, is recommended, in preference to all others, by Mr. Talbot, especially for taking portraits.

The paper, after exposure for the due time in the camera, is to be again covered from the light, taken out, and subjected to another process; for as yet it has no pictorial appearance. To bring out this effect, it must be washed with the gallo-nitrate of silver, and then be gently warmed. In a few seconds the portions of the paper upon which the light has acted will begin to darken, and eventually grow quite black, while the rest of the paper retains its original hue. Even though the pictorial impression be very faint, it may be brought out by a second application of the same solution. The operator should watch the gradual development of the tints; and when it is sufficient, he should fix them by dipping the paper in water, drying it slightly with blotting paper, then washing it over with a solution of bromide of potassium

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containing 100 grains of that salt, dissolved in 8 or 10 ounces of water. Strong brine will also answer, but not so well. Similar calotype pictures may be made by using the bright light emitted from lime ignited by the oxy-hydrogen flame; as is practised in making the Daguerreotype portraits at night.

In all the photographic pictures the lights and shades of the object are reversed; but they may be made conformable to nature by rendering the paper transparent with white wax scraped upon its back, melting this in by rubbing it with a hot smoothing iron, after it is placed between two sheets of common paper, then laying it upon paper imbued with bromide of potassium, and exposing it to sunshine. Portraits are best taken by means of a lens, whose focal length is 3 or 4 times only greater than the diameter of the aperture. (See PHOTOGRAPHY.)

CAMBRIC. (*Batiste*, Fr.; *Kammertuch*, Germ.) A sort of very fine and rather thin linen fabric, first made at Cambray. An excellent imitation of this fabric is made in Lancashire, woven from fine cotton yarn hard twisted. Linen cambric of a good quality is also now manufactured in the United Kingdom from power-spun flax.

CAMLET, or CAMBLET. A light stuff, much used for female apparel. It is made of long wool hard spun, sometimes mixed in the loom with cotton or linen yarn.

CAMPHOR, OR CAMPHIRE. This immediate product of vegetation was known to the Arabs under the names of *kamphur* and *kaphur*, whence the Greek and Latin name *camphora*. It is found in a great many plants, and is secreted, in purity, by several laurels; it occurs combined with the essential oils of many of the *labiacæ;* but it is extracted, for manufacturing purposes only, from the *Laurus camphora*, which abounds in China and Japan, as well as from a tree which grows in Sumatra and Borneo, called, in the country, *Kapour barros*, from the name of the place where it is most common. The camphor exists, ready formed, in these vegetables, between the wood and the bark; but it does not exude spontaneously. On cleaving the tree *Laurus sumatrensis*, masses of pure camphor are found in the pith.

The wood of the laurus is cut into small pieces, and put, with plenty of water, into large iron boilers, which are covered with an earthen capital or dome, lined within with rice straw. As the water boils, the camphor rises with the steam, and attaches itself as a sublimate to the stalks, under the form of granulations of a gray color. In this state, it is picked off the straw, and packed up for exportation to Europe.

Formerly Venice held the monopoly of refining camphor, but now France, England, Holland, and Germany refine it for their own markets. All the purifying processes proceed on the principle that camphor is volatile at the temperature of 400° F. The substance is mixed, as intimately as possible, with 2 per cent. of quicklime, and the mixture is introduced into a large bottle made of thin uniform glass, sunk in a sand bath. The fire is slowly raised till the whole vessel becomes heated, and then its upper part is gradually laid bare in proportion as the sublimation goes on. Much attention and experience are required to make this operation succeed. If the temperature be raised too slowly, the neck of the bottle might be filled with camphor before the heat had acquired the proper subliming pitch; and, if too quickly, the whole contents might be exploded. If the operation be carried on languidly, and the heat of the upper part of the bottle be somewhat under the melting point of camphor, that is to say, a little under 350° F., the condensed camphor would be snowy, and not sufficiently compact and transparent to be saleable. Occasionally, sudden alternations of temperature cause little jets to be thrown up out of the liquid camphor at the bottom upon the cake formed above, which soil it, and render its re-sublimation necessary.

If, to the mixture of 100 parts of crude camphor and 2 of quicklime, 2 parts of bone-black, in fine powder, be added, the small quantity of coloring matter in the camphor will be retained at the bottom, and whiter cakes will be produced. A spiral slip of platina foil immersed in the liquid may tend to equalize its ebullition.

By exposing some volatile oils to spontaneous evaporation, at the heat of about 70° F., Proust obtained a residuum of camphor; from oil of lavender, 25 per cent. of its weight; from oil of sage, 12½; from oil of marjoram, 10.

Refined camphor is a white translucid solid, possessing a peculiar taste and smell It may be obtained, from the slow cooling of its alcoholic solution, in octahedral crystals. It may be scratched by the nail, is very flexible, and can be reduced into powder merely by mixing it with a few drops of alcohol. Its specific gravity varies from 0·985 to 0·996. Mixed and distilled with six times its weight of clay, it is decomposed, and yields a golden yellow aromatic oil, which has a flavour analogous to that of a mixture of thyme and rosemary: along with a small quantity of acidulous water tinged with that oil, charcoal remains in the retort. In the air, camphor takes fire on contact of an ignited body, and burns all away with a bright fuliginous flame.

Camphor is little soluble in water; one part being capable of communicating smell and taste to 1000 of the fluid. 100 parts of alcohol, spec. grav. 0·806, dissolve 120 parts of camphor, at ordinary temperatures. It is separated, in a pulverulent state, by water. Ether and oils, both expressed and volatile, also dissolve it.

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When distilled with eight parts of aquafortis, camphor is converted into camphoric acid. Camphor absorbs 144 times its volume of muriatic acid gas, and is transformed into a colorless transparent liquid, which becomes solid in the air, because the acid attracts humidity, which precipitates the camphor. One part of strong acetic acid dissolves two parts of camphor. By my analysis, camphor consists of 77·38 carbon, 11·14 hydrogen, and 11·48 oxygen. Berzelius's numbers are certainly erroneous.

CAMWOOD. An article imported from Sierra Leone, which seems to possess similar dyeing powers with Brazil or Nicaragua wood.

CANDLE. (*Chandelle*, Fr.; *Kerze, Licht*, Germ.) I shall first briefly describe the ordinary manufacture of candles. They are either dipped or moulded. But the first part of the process is the sorting of the tallow. Mutton suet with a proportion of ox-tallow is selected for mould candles, because it gives them gloss and consistence. Coarser tallow is reserved for the dipped candles. After being sorted, it is cut into small pieces, preparatory to being melted or *rendered;* and the sooner this is done after the fat is taken from the carcass the better, because the fibrous and fleshy matters mixed with it promote its putrefaction. Tallow is too commonly melted by a naked fire applied to the bottom of the vessel, whereas it should be done either in a cold set pan, where the flame plays only round the sides a little way above the bottom, or in a steam-cased pan. After being fused a considerable time, the membraneous matters collect at the surface, constituting the *cracklings* used sometimes for feeding dogs, after the fat has been squeezed out of it by a press. The liquid tallow is strained through a sieve into another copper, where it is treated with water at a boiling temperature in order to wash it. After a while, when the foul water has settled to the bottom, the purified tallow is lifted out, by means of tinned iron buckets, into tubs of a moderate size, where it concretes, and is ready for use.

It is a remarkable circumstance, that the wicks for the best candles are still cotton rovings imported from Turkey, notwithstanding the vast extension and perfection of cotton-spinning in this country. Four or more of these Turkey skeins, according to the intended thickness of the wick, are wound off at once into bottoms or clews, and afterward cut by a simple machine into lengths corresponding to those of the candles to be made. Mr. Colebank obtained a patent, in June, 1822, for a machine for cutting, twisting, and spreading wicks, which, though convenient, does not seem to have come into general use. The operations are performed upon a series of threads at once. The apparatus is placed in a box, in front of which the operator sits. A reel extends across the box, at the hinder part, upon which the cotton threads have been previously wound: from this reel they are drawn off in proper lengths, doubled, and cut by an ingenious mechanism. By dipping the wicks into the melted tallow, rubbing them between the palms of the hands, and allowing the tallow which adheres to harden, they may be arranged with facility upon the broaches for the purpose of dipping. The dipping-room is furnished with a boiler for melting the tallow, the dipping-mould, or cistern, and a large wheel for supporting the broaches. From the ceiling of the workshop a long balance-shaped beam is suspended, to one end of which a wooden frame is attached for holding the broaches with the wicks arranged at proper distances. The opposite arm is loaded with a weight to counterbalance the wooden frame, and to enable the workman to ascertain the proper size of the candles. The end of the lever which supports the frame is placed immediately above the dipping-cistern; and the whole machine is so balanced that by a gentle pressure of the hand, the wicks are let down into the melted tallow as often as may be required.

The following convenient apparatus for dipping candles has been long in use at Edinburgh. In the centre of the dipping-room a strong upright post A A, *fig.* 320, is erected, with turning iron pivots at its two ends. Near its middle, six mortises are cut at small distances from one another, into each of which is inserted a long bar of wood B B, which moves vertically upon an iron pin, also passing through the middle of the shaft. The whole presents the appearance of a large horizontal wheel with twelve arms. A complete view of two of them only is given in the figure. From the extremity of each arm is suspended a frame, or port, as the workmen call it, containing 6 rods, on each of which are hung 18 wicks, making the whole number of wicks upon the wheel 1296. The machine, though apparently heavy, turns round by the smallest effort of the workman; and each port, as it comes in succession over the dipping-mould, is gently pressed downwards, by which means the wicks are regularly immersed in melted tallow. As the arms of the lever are all of the same length, and as each is loaded with nearly the same weight, it is obvious that they will all naturally assume a horizontal position. In order, however, to prevent any oscillation of the machine in turning round, the levers are kept in a horizontal position by means of small chains *a a*, one end of which is fixed to the top of the upright shaft, and the other terminates in a small square piece of wood, *b*, which exactly fills the notch *c* in the lever. As one end of the lever must be depressed at each dip, the square piece of wood is thrown out of the notch by the workmen pressing down the handle D, which communicates with the small lever e, inserted into a groove in the bar B. In order that the square piece of wood fixed in one extremity of the chain may recover its position upon the workman's raising the port, a small cord is attached to it, which passes over a pulley inserted in a groove near c, and communicates with another pulley and weight, which draws it forward to the notch. In this way the operation of dipping may be conducted by a single workman with perfect ease and regularity, and even dispatch. No time is lost, and no unnecessary labour expended, in removing the ports after each dip; and, besides, the process of cooling is much accelerated by the candles being kept in constant motion through the air. The number of revolutions which the wheel must make, in order to complete one operation, must obviously depend upon the state of the weather and the size of the candles; but it is said that, in moderately cold weather, not more than two hours are necessary for a single person to finish one wheel of candles of a common size. Upon the supposition, therefore, that six wheels are completed in one day, no less a number than 7776 candles will be manufactured in that space of time by one workman.

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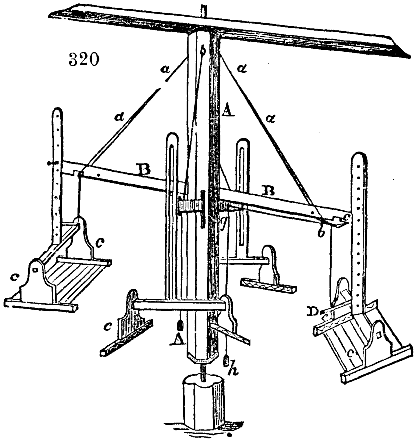

I shall next describe the process of moulding, which, if possible, is even less complicated in its details than that of dipping. The moulds are made of some metallic substance, usually pewter, and consist of two parts. The shaft or great body of the mould is a hollow cylinder, finely polished in the inside, and open at both extremities. The top of the mould is a small metallic cup, having a moulding within-side, and a hole to admit the wick. The two parts are soldered together, and when united, as will readily be imagined, have the shape of a moulded candle. A third piece, called the foot, is sometimes added: it is a kind of small funnel, through which the liquid tallow runs into the mould, and, being screwed to the opposite extremity of the shaft, is removeable at pleasure. This additional piece may certainly be useful in very mild weather, since, by removing it, the candles may be drawn more easily from the moulds; but, in general, it may be dispensed with.

Eight or twelve of these moulds, according to their size, are fixed in a frame, which bears a great resemblance to a wooden stool, the upper surface of which forms a kind of trough. The top of the moulds points downwards, and the other extremity, which is open, is inserted into the bottom trough or top of the stool, and made quite level with its upper surface. In order to introduce the wicks into the mould, the workman lays the frame upon its side on an adjoining table, and holding in his left hand a quantity of wicks, previously cut to the proper length, he introduces into the mould a long wire with a hooked point. As soon as the hook of the wire appears through the hole in the top of the mould, he attaches to it the looped end of the wick, and, immediately drawing back the wire, carries the wick along with it. In this manner each mould in succession is furnished with a wick. Another workman now follows, and passes a small wire through the loop of each wick. This wire is obviously intended to keep the wick stretched, and to prevent it from falling back into the mould upon the frame being placed in the proper position for filling. The frame is then handed to the person that fills the moulds, who previously arranges the small wires in such a manner that each wick may be exactly in the axis of the mould.

The moulds are filled by running tallow into each of them, or into the trough, from a cistern furnished with a cock, and which is regularly supplied with tallow of the proper temperature from an adjoining boiler. When the workman observes that the moulds are nearly half filled he turns the cock, and laying hold of that portion of the wick which hangs out of the moulds, pulls it tight, and thus prevents any curling of the wick, which might injure the candles: he then opens the cock, and completes the process of filling. The frame is now set aside to cool; and when the tallow has acquired a proper consistence, which the workman easily discovers by a snapping noise emitted by the candles upon pressing his thumb against the bottom of the moulds, he first withdraws the small wires which kept the wicks tense, and then, scraping off the loose tallow from the top of the frame with a small wooden spade, he introduces a bodkin into the loop of the wick, and thus draws each candle in succession from its mould. The candles are now laid upon a table for the inspection of the exciseman, and afterwards removed to the storehouse. Previous to storing them up, some candle-makers bleach their candles, by exposing them to the air and dews for several days. This additional labour can be necessary only when the dealer is obliged to have early sales; for if the candles are kept for some months, as they ought to be, before they are brought to market, they become sufficiently whitened by age.

Wax candles.—Next to tallow, the substance most employed in the manufacture of candles is wax. Wax candles are made either by the hand or with a ladle. In the former case, the wax, being kept soft in hot water, is applied bit by bit to the wick, which is hung from a hook in the wall; in the latter, the wicks are hung round an iron circle, placed immediately over a large copper-tinned basin full of melted wax, which is poured upon their tops, one after another, by means of a large ladle. When the candles have by either process acquired the proper size, they are taken from the hooks, and rolled upon a table, usually of walnut-tree, with a long square instrument of box, smooth at the bottom.

A few years ago I made a set of experiments upon the relative intensities of light, and duration of different candles, the results of which are contained in the following table.

Number in a pound.	Duration of a candle.		Weight in grains.	Consumption per hour in grains.	Proportion of light.	Economy of light.	Candles equal one Argand.
	h.	m.					
10 mould - - -	5	9	682	132	12¼	68	5·7
10 dipped - - -	4	36	672	150	13	65½	5·25
8 mould - - -	6	31	856	132	10½	59½	6·6
6 ditto - - -	7	2½	1160	163	14⅔	66	5·0
4 ditto - - -	9	3·6	1707	186	20¼	80	3·5
Argand oil flame	—		—	512	69·4	100	

A Scotch mutchkin, or ⅛ of a gallon of good seal oil, weighs 6010 gr., or 13$\frac{1}{10}$ oz., avoirdupois, and lasts in a bright Argand lamp 11 hours 44 minutes. The weight of oil it consumes per hour is equal to 4 times the weight of tallow in candles 8 to the pound, and $\frac{1}{7}$ the weight of tallow in candles 6 to the pound. But, its light being equal to that of 5 of the latter candles, it appears from the above table that 2 pounds weight of oil, value 9*d.* in an Argand, are equivalent in illuminating power to 3 pounds of tallow candles, which cost about two shillings. The larger the flame in the above candles the greater the economy of light.

In June, 1825, M. Gay Lussac obtained a patent in England for making candles from *margaric and stearic acids*, improperly called *stearine*, by converting tallow into the above fat acids by the following process:—Tallow consists, by Chevreul's researches, of stearine, a solid fat, and elaine, a liquid fat; the former being in much the larger proportion. When tallow is treated with an alkaline body, such as potash, soda, or lime, it is saponified; that is, its stearine and elaine become respectively stearic and elaic acids, and, as such, form compounds with these bases. When by the action of an acid, such as the sulphuric or muriatic, these combinations are decomposed, the fats reappear in the altered form of stearic and elaic acids; the former body being harder than tallow, and of a texture somewhat like spermaceti, the latter body being fluid, like oil. "The decomposition of the soap should be made," says the patentee, "in a large quantity of water, kept well stirred during the operation, and warmed by steam introduced in any convenient way. When the mixture has been allowed to stand, the acid of the tallow or fat will rise to the surface, and the water being drawn off will carry the alkaline or saline matters with it; but if the acids of the tallow should retain any portion of the salts, fresh water may be thrown upon it, and the whole well agitated, until the acids have become perfectly free from the alkaline matters; and when allowed to cool, the acids will be formed into a solid mass. This mass is now to be submitted to considerable pressure in such an apparatus as is employed in expressing oil from seeds; when the liquid acid will run off in the form of a substance resembling oil, leaving a solid matter, similar, in every respect, to spermaceti, which is fit for making candles."

The wick to be used in the manufacture of these improved candles, and which forms one of the features of this invention, is to be made of cotton yarn, twisted rather hard, and laid in the same manner as wire is sometimes coiled round bass strings of musical instruments. For this purpose straight rods or wires are to be procured, of suitable lengths and diameters, according to the intended size of the candles about to be made: and these wires, having been covered with cotton coiled round them as described, are to be inserted in the candle moulds as the common wicks are; and when the candle

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is made, and perfectly hard, the wire is to be withdrawn, leaving a hollow cylindrical aperture entirely through the middle of the candle. See STEARINE.

CANDLES. Messrs. Hempel and Blundell have given a very minute account of the process for making palm-oil, stearic and margaric acids, in the specification of their patent for this mode of manufacturing candles :—

1. Their first process is called *crystallization*, which consists in pouring the melted palm-oil into iron pans, and allowing it to cool slowly, whereby, at about 75° F., the elaine separates from the crystalline stearine and margarine.

2. The concreted oil is subjected to the action of an hydraulic press, in order to separate the elaine from the solid fats.

3. This process is called *oxidation*. To 104 lbs. of the stearine and margarine, melted in an iron pan, about 12 lbs. of slaked and sifted quicklime are added, with diligent stirring, during which the temperature is to be slowly raised to 240° F., and so maintained for about three hours, till a perfect chemical combination takes place. This is shown by the mass becoming thin, transparent, and assuming a glassy appearance when it cools. The fire being now withdrawn, cold water is added very gradually at first, with brisk stirring till the whole mass falls into a state of powdery granulation, when it is passed through a wire sieve to break down any lumps that may remain.

4. *Separation of the stearic and margaric acids* from the lime. For this purpose, as much muriate of lime (chlorcalcium) is taken as will, with its equivalent quantity of sulphuric acid (8 lbs. of dry chlorcalcium require 7 lbs. of the strongest sulphuric acid), produce as much muriatic acid as will dissolve the lime combined with the fat acids; and therefore that quantity of muriate of lime dissolved in water must be treated with as much sulphuric acid as will saturate its lime and throw it down in the state of sulphate of lime. Add the supernatant solution of muriatic acid in such proportion to the stearate and margarate of lime as will rather more than saturate the lime. Three pounds of muriatic acid diluted with 9 lbs. of water are stated as enough for 1 lb. of lime. This mixture is to be let alone for 3 or 4 days, in order to insure the complete separation of the lime from the fat acids; and then the mixture is heated so as to melt and cause them to separate in a stratum on the top of the liquid. The resulting muriate of lime is drawn off into another tub, and decomposed by its dose of sulphuric acid, so as to liberate its muriatic acid for a fresh operation.

5. The fat acids, being well washed by agitation with hot water, are then set to cool and crystallize, in which state they are subjected to the action of the hydraulic press, at a temperature of 75° F., whereat the margaric acid runs off from the solid stearic acid.

6. *Bleaching*. The stearic acid is taken from the press, and exposed upon water in large shallow vessels placed in the open air, where it is kept at the melting temperature from 8 to 12 hours, stirring meanwhile, in order to promote the blanching action of the atmosphere. The margaric acid is bleached in a similar manner in separate vessels.

7. *Refining process*. The fat is warmed again, and poured in a liquid state into an agitating tub; where, for every 1,000 lbs. of the stearic acid, about 2½ lbs. of common black oxide of manganese, and 40 lbs. of concentrated sulphuric acid, diluted with 200 lbs. of pure water, are to be used. This solution (" mixture"), while warm from the heat evolved in diluting the acid, is placed in a suitable vessel above the agitating tub. The stearic acid being at the melting point, in the vessel below, agitation is to be given with a revolving shaft, while the mixed manganese and acid are run slowly down into it, till the whole be well mixed, which generally requires about two hours. The mass is allowed to lie in this state for 48 hours; after which it may be boiled by steam for 2 or 3 hours, when it will be sufficiently refined. The sulphuric acid, which is at the bottom, is now run off, and the stearic acid which remains is well washed with pure water. It is then put into large conical vessels of stoneware, enclosed in a box or jacket, kept warm by steam-heat, and lined with conical bags of suitable strong filtering paper, through which, being warm, it finds its way; and when the stearic acid has been thus filtered, it is run into blocks, when it will be found to be a beautiful stearic acid or palm-wax, and is ready to be made into candles in the usual way.

On the above process with manganese and diluted sulphuric acid, it may be observed, that no solution or chemical action takes place between them, and their joint use seems therefore most problematical. The patentees proceed to describe other processes of refining, in which sulphate of manganese, with common salt, phosphoric acid (highly concentrated), and oxalic acid, are used, and in my opinion either ignorantly or for the purpose of mystification; for, as prescribed, they can serve no possible purpose of purifying the stearnine.

The chief solid constituent of palm-oil is margaric acid. This they direct to be melted with tallow, in the proportion of from 10 to 20 lbs. of the former to 100 lbs. of the latter. See *Newton's Journal, C. S.*, xi. 207.

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I was told by M. Runge, at Berlin, that he was the inventor of the process for making white margaric acid from palm-oil, and that Hempel had got it somehow from him, but most imperfectly, as it would appear. Hempel died here in the midst of the above patent operations; but the specification is, no doubt, a specimen of his manufacture of Runge's margaric acid. He gave me a splendid pearly-looking sample.

Mr. Wilson of Belmont, Vauxhall, obtained in August, 1844, a patent for improvements in treating fats for making candles. If distilled fats are used in making composite candles, they are bleached and hardened in that operation. When palm-oil is the material, it is first saponified; then distilled, granulated by fusion and slow cooling, and cold-pressed; by which means stearic acid and a light coloured oil are obtained; which may be mixed with the stearine of cocoa-nut oil, or other stearine. A cheaper article may be had by mixing the entire product of the above distillation with half its weight of distilled and cold-pressed stearic acid of tallow. Tallow is deprived of its oleine by pressure, accompanied by artificial cold if necessary; this being added to the other hard matter, the mixture is converted into fatty acids, and distilled, and the entire product of distillation is employed for making candles; or it may be pressed to make them harder. As distilled stearic acid is more crystalline than undistilled, 2 or 4 per cent. of wax may be added to assist the combination of the fatty acid with the stearine.—*Newton's Journal*, xxvi. 165.

Candles consisting of alternate layers of tallow and stearine have been made by dipping their wicks alternately in these two fatty bodies in a fluid state. Mr. W. Sykes has gone to the expense of a patent on the contrivance. The wicks are impregnated with a solution of bismuth or borax.

New patent candle manufacture.—Vegetable tallow melts at a degree of heat somewhat above that of animal tallow, but considerably below that of vegetable wax. Mr. Wilson of Belmont, Vauxhall, treats his tallow by putting 6 tons of it into an iron still capable of holding 9 tons, heats it gradually to 350° Fahr., and then adds gradually 1440 lbs. of sulphuric acid of 1·8 sp. gr. At the expiration of about 2 hours, the tallow is pumped into a vessel, containing water slightly acidulated with sulphuric acid; and is therein agitated by free steam passing through it for 2 hours. The materials are then left to repose for 6 hours; both this vessel and the former should be provided with a cover and a means of conveying the gases which may be evolved into a chimney. The vegetable tallow is next distilled in such a manner that the atmosphere is excluded. This is best effected by the use of steam highly heated, which he introduces into the still, in numerous jets below the tallow. The distilled products are received into condensers, and they may be used alone, or they may be mixed with other matters for making the best class of candles. The patentee improves paraffine by a like process. He makes candles with 2 or 3 wicks, by mixing palm-oil pressed with tallow, or the above distilled fat, for burning in candle lamps.—*Newton's Journal*, xxxv. 108.

The following is one of his later processes. Candles and night-lights are manufactured by Mr. Wilson of Vauxhall, by combining palm-oil which has been bleached by the atmosphere with distilled fatty acids, with or without other fats. By combining one part of crude cocoa-nut oil, one part of cold pressed atmospherically bleached palm-oil, and one part of unpressed palm-oil, acidified by sulphuric acid and distilled, an excellent product is obtained; and other distilled fatty acids may be used, pressed or unpressed. This distillation is effected by transmitting through the fat contained in an iron still, steam at about 600° or 700° Fahr., heated by passing through iron pipes laid in a fire. The steam is transmitted till the oily matter is heated to about 350°; the vapours produced being carried into a high shaft by a pipe from the cover of the iron vessel. The hot oily matter is then run into another vessel made of brick lined with lead, and sunk in the ground, for the purpose of supporting the brick-work under or against the internal pressure of the fluid. It has a wooden cover lined with lead, directly beneath which, and extending across the vessel, is a leaden pipe, 1 inch in diameter, having a small hole in each side, at every six inches of its length; and through this pipe is introduced a mixture of 1000 lbs. of sulphuric acid, sp. gr. 1·8., and the same weight of water. The introduction of the mixture which falls in divided jets into the heated fat, produces violent ebullition; and by this means the acid and fat are perfectly incorporated before the action of the acid becomes apparent by any considerable discoloration of the fat. As the ebullition ceases, the fat gradually blackens; and the matter is allowed to remain for 6 hours after the violent ebullition has ceased. The offensive fumes produced are carried off by a large pipe, which rises from the top of the vessel, then descends, and afterwards rises again into a high chimney. At the downward part of this pipe a small jet of water is kept playing, to condense such parts of the vapours as are condensable. At the end of the 6 hours above mentioned, the operation is complete, and the product is then pumped into another close vessel and washed by being boiled up (by means of free steam) with half its bulk of water. The water is drained off, and the washing repeated, except that in the second washing the water is acidulated with 100 lbs. of sulphuric acid. The ultimate product is allowed to settle for 24 hours; after which it is distilled in an atmosphere of steam, once or oftener, until well purified; and the product of distillation is again washed, and after being pressed in the solid state, is applied to the manufacture of candles.—*Newton's London Journal*, xxvi. and xxxv.

CANE-MILL. See Mill and Sugar.

CANNON. For the composition of these implements of destruction, see Bronze.

CANVASS. (*Canevas*, Fr.; *Segeltuch*, Germ.) It has been found that sails of ships made with the selvages and seams of the canvass running down parallel to their edges, are very apt to bag, and become torn in the middle, from the strain to which they are subjected by the pressure of the wind. To obviate this inconvenience, a mode of making sails, with the seams and selvages running diagonally, was proposed by Admiral Brooking, and a patent granted to him for the same on the 4th of September, 1828. The invention of Messrs. Ramsay and Orr, which we are about to describe, has a similar object, viz., that of giving additional strength to sails by a peculiar manner of weaving the canvass of which they are made.

The improvement proposed under their patent of March, 1830, consists in weaving the canvass with diagonal threads; that is, placing the weft yarn, or shoot, in weaving, at an oblique angle to the warp yarns, instead of making the decussation of the warp, or weft threads, or yarns, at right angles to each other, as in the ordinary mode of weaving.

To accomplish this object, the loom must be peculiarly constructed; that is, its warp and work beams must stand at an oblique angle with the sides of the loom, and the batten and slay must be hung in a peculiar manner, in order to beat up the weft, or shoot, in lines ranging diagonally with the warp. No drawing is shown of the method by which this arrangement of the loom is to be made, but it is presumed that any weaver would know how to accomplish it: the invention consisting solely in producing sail-cloth with the threads or yarns of the weft ranging diagonally at any desired angle with the direction of the warp thread.

CAOUTCHOUC, GUM-ELASTIC, or INDIAN-RUBBER (*Federharz*, Germ.), occurs as a milky juice in several plants, such as the *siphonia cahuca*, called also *hevea guianensis*, *cautschuc*, *jatropha elastica*, *castilleja elastica*, *cecropia pellata*, *ficus religiosa* and *undica*, *urceolaria elastica*, &c. It is, however, extracted chiefly from the first plant, which grows in South America and Java. The tree has incisions made into it through the bark in many places, and it discharges the milky juice, which is spread upon clay moulds, and dried in the sun, or with the smoke of a fire, which blackens it.

The juice itself has been of late years imported. It is of a pale yellow color, and has the consistence of cream. It becomes covered, in the bottles containing it, with a pellicle of concrete caoutchouc. Its spec. grav. is 1·012. When it is dried, it loses 55 per cent. of its weight: the residuary 45 is elastic gum. When the juice is heated, it immediately coagulates, in virtue of its albumen, and the elastic gum rises to the surface. It mixes with water in any proportion; and, when thus diluted, it coagulates with heat and alcohol as before.

The specific gravity of caoutchouc is 0·925, and it is not permanently increased by any degree of pressure. By cold or long quiescence, it becomes hard and stiff. When the milky juice has become once coherent, no means hitherto known can restore it to the emulsive state. By long boiling in water it softens, swells, and becomes more readily soluble in its peculiar menstrua; but when exposed to the air, it speedily resumes its pristine consistence and volume. It is quite insoluble in alcohol; but in ether, deprived of alcohol by washing with water, it readily dissolves, and affords a colorless solution. When the ether is evaporated, the caoutchouc becomes again solid, but is somewhat clammy for a while. When treated with hot naphtha, distilled from native petroleum, or from coal tar, it swells to 30 times its former bulk; and if then triturated with a pestle, and pressed through a sieve, it affords a homogeneous varnish, which being applied by a flat edge of metal or wood to cloth, prepares it for forming the patent water-proof cloth of Mackintosh. Two surfaces of cloth, to which several coats of the above varnish have been applied, are, when partially dried, brought evenly in contact, and then passed between rollers, in order to condense and smooth them together. This double cloth is afterwards suspended in a stove-room to dry, and to discharge the disagreeable odour of the naphtha.

Caoutchouc dissolves in the fixed oils, such as linseed oil, but the varnish has not the property of becoming concrete upon exposure to air.

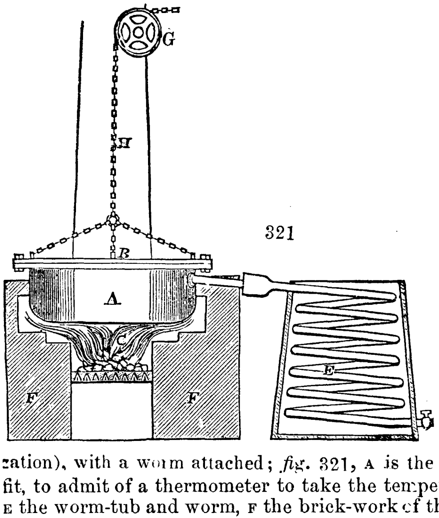
It has been lately asserted that caoutchouc is soluble in the oils of lavender and sassafras.

It melts at 248° F., and stands afterwards a much higher heat without undergoing any further change. When the melted caoutchouc is exposed to the air, it becomes hard on the surface in the course of a year. When kindled it burns with a bright flame and a great deal of smoke.

Neither chlorine, sulphurous acid gas, muriatic acid gas, ammonia, nor fluosilicic acid gas affects it, whence it forms very valuable flexible tubes for pneumatic chemistry. Cold sulphuric acid does not readily decompose it, nor does nitric acid, unless it be somewhat strong. The strongest caustic potash ley does not dissolve it even at a boiling heat.

Caoutchouc, according to my experiments, which have been confirmed by those of Mr. Faraday, contains no oxygen, as almost all other solid vegetable products do, but is a mere compound of carbon and hydrogen, in the proportion, by my results, of 90 carbon to 10 hydrogen, being three atoms of the former to two of the latter. Mr. Faraday obtained only 87·2 carbon, from which I would infer that some of the carbon, which in this substance is difficult to acidify by peroxyde of copper, had escaped its action. It is obvious that too little carbonic acid gas may be obtained, but certainly not more than corresponds to the carbon in the body. No carbon can be created in the process of ultimate analysis by pure peroxyde of copper such as I employed; and I repeated the ignition after attrition of the mixture used in the experiment. Melted caoutchouc forms a very excellent chemical lute, as it adheres very readily to glass vessels, and withstands the corrosive action of acid vapors. This substance is much used for effacing the traces of plumbago pencils, whence it derived the name of Indian-rubber. It has been lately employed very extensively for making elastic bands or braces. The caoutchouc bottles are skilfully cut into long spiral slips, which are stretched, and kept extended till nearly deprived of their elasticity, and till they form a thread of moderate fineness. This thread is put into a braid machine, and covered with a sheath of cotton, silk, linen, or worsted. The clothed caoutchouc is then laid as warp in a loom, and woven into an elegant riband. When woven, it is exposed upon a table to the action of a hot smoothing iron, which restoring to the caoutchouc all its primitive elasticity, the riband retracts considerably in length, and the braiding corrugates equally upon the caoutchouc cores. Such bands possess a remarkable elasticity, combined with any desired degree of softness. Sometimes cloth is made of these braided strands of caoutchouc used both as warp and as weft, which is therefore elastic in all directions. When a light fabric is required, the strands of caoutchouc, either naked or braided, are alternated with common warp yarns. For this mixed fabric a patent has been obtained. The original manufacturer of these elastic webs is a major in the Austrian service, who has erected a great factory for them at St. Denys, near Paris. See Elastic Bands.

Mr. William Henry Barnard, in the course of some experiments upon the impregnation of ropes with caoutchouc, at the factory of Messrs. Enderby, at Greenwich, discovered that when this substance was exposed to a heat of about 600° F. it resolved itself into a vapor, which, by proper refrigeratory methods, was condensable into a liquid possessing very remarkable properties, to which the name caoutchoucine has been given. For this invention "of a solvent not hitherto used in the arts" Mr. Barnard obtained a patent, in August, 1833. His process for preparing it is described in his specification as follows:—I take a mass of the said caoutchouc, or Indian rubber, as imported, and having cut it into small lumps, containing about two cubic inches each (which I prefer), I throw these lumps into a cast-iron still (which I find adapted for the purpose, and a diagram of which is annexed to, and forms part of, this my specification), with a worm attached; *fig.* 321, A is the still, B the cover ground to a metallic fit, to admit of a thermometer to take the temperature; C the fire-place, D the ash-pit, E the worm-tub and worm, F the brick-work of the still, G a roller and carriage, in conjunction with a crane, or other means, to raise the cover to take out the residue, and to charge the same; H the chain.



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"I then apply heat to the still in the usual manner, which heat is increased until the thermometer ranges at 600 degrees of Fahrenheit, or thereabouts. And, as the thermometer ranges progressively upwards to 600 degrees of Fahrenheit, a dark-coloured oil or liquid is distilled over, which I claim as my said invention, such liquid being a solvent of caoutchouc, and other resinous and oleaginous substances. When the thermometer reaches 600 degrees, or thereabouts, nothing is left in the still but dirt and charcoal.

I have found the operation of distillation to be facilitated by the addition of a portion of this oil, either previous or subsequent to rectification, as hereinafter mentioned, in the proportion of one third of oil to two thirds of caoutchouc.

I afterwards subject the dark-colored liquid thus distilled to the ordinary process of rectification, and thereby obtain fluids varying in specific gravity, of which the lightest hitherto has not been under 670, taking distilled water at 1000, which fluids I also claim as my said invention.

At each rectification the color of the liquid becomes more bright and transparent, until, at the specific gravity of 680, or thereabouts, it is colorless and highly volatile.

In the process of rectification (for the purpose of obtaining a larger product of the oil colorless) I put about one third of water into the still. In each and every state the liquid is a solvent of caoutchouc, and several resinous and oleaginous substances, and also of other substances (such as copal), in combination with very strong alcohol.

Having experienced much difficulty in removing the dirt which adheres to the bottom of the still, I throw into the still lead and tin in a state of alloy (commonly called solder), to the depth of about half an inch, and, as this becomes fused, the dirt which lies on the surface of it is more easily removed.

Objections have been made to the smell of this liquid: I have found such smell removed by mixing and shaking up the liquid with nitro-muriatic acid, or chlorine, in the proportion of a quarter of a pint of the acid (of the usual commercial strength) to a gallon of the liquid.

The discovery of the chemical solvent, which forms the subject of the patent above described, has excited considerable interest in the philosophic world, not only from its probable usefulness as a new article of commerce, but also from two very extraordinary characteristics which it is found to possess, viz., that, in a liquid state, it has less specific gravity than any other liquid known to chemists, being considerably lighter than sulphuric ether, and, in a state of vapor, is heavier than the most ponderous of the gases.

Its elementary constituents are,

Carbon - - - - - -	6·812 - - - -	8 proportions.
Hydrogen - - - - -	1·000 - - - -	7 ditto.

This new material (when mixed with alcohol) is a solvent of all the resins, and particularly of copal, which it dissolves, without artificial heat, at the ordinary temperature of the atmosphere; a property possessed by no other solvent known; and hence it is peculiarly useful for making varnishes in general. It also mixes readily with oils, and will be found to be a valuable and cheap menstruum for liquefying oil-paints; and, without in the slightest degree affecting the most delicate colors, will, from its ready evaporation, cause the paint to dry almost instantly.

Cocoa-nut oil, at the common temperature of the atmosphere, always assumes a concrete form; but a portion of this caoutchoucine mixed with it will cause the oil to become fluid, and to retain sufficient fluidity to burn in a common lamp with extraordinary brilliancy.

Caoutchoucine is extremely volatile; and yet its vapor is so exceedingly heavy, that it may be poured, without the liquor, from one vessel into another like water.

Hitherto the greater part of the caoutchouc has been imported into Europe from South America, and the best from Para; but of late years a considerable quantity has been brought from Java, Penang, Sincapore, and Assam. About twelve years ago, Mr. William Griffith published an interesting report upon the *Ficus elastica*, the caoutchouc tree of Assam, which he drew up at the request of Captain Jenkins, agent in that country to the Governor-General of India. This remarkable species of fig-tree is either solitary, or in twofold or threefold groups. It is larger and more umbrageous than any of the other trees in the extensive forest where it abounds, and may be distinguished from the other trees, at a distance of several miles, by the picturesque appearance produced by its dense, huge, and lofty crown. The main trunk of one was carefully measured, and was found to have a circumference of no less than 74 feet; while the girth of the main trunk along with the supports immediately round it, was 120 feet. The area covered by the expanded branches had a circumference of 610 feet. The height of the central tree was 100 feet.

It has been estimated, after an accurate survey, that there are 43,240 such noble trees within a length of 30 miles, and breadth of 8 miles of forest near Ferozepoor, in the district of Chardwar, in Assam.

Lieutenant Veitch has since discovered that the *Ficus elastica* is equally abundant in the district of Naudwar. Its geographical range in Assam seems to be between 25 deg. 10 min. and 27 deg. 20 min. of north latitude, and between 90 deg. 40 min. and 95 deg. 30 min. of east longitude. It occurs on the slopes of the hills, up to an elevation of probably 22,500 feet. This tree is of the banyan tribe, famed for its pillared shade, "whose daughters grow about the mother tree," which has furnished the motto *tot rami, quot arbores*, to the Royal Asiatic Society. Species of this genus afford grateful shade, however, in the tropical regions of America, as well as Asia.

Many species of other trees yield a milky tenacious juice, of which birdlime has been frequently made; as *Artocarpus integrifolia*, and *Lakoocha*, *Ficus indica* and *religiosa*, also *F. Tsiela*, *Roxburghii*, *glomerata*, and *oppositifolia*. From some of these an inferior kind of caoutchouc has been obtained.

The juice of the *Ficus elastica* of Chardwar is better when drawn from the old than from the young trees, and richer in the cold season than in the hot. It is extracted by making incisions a foot apart, across the bark down to the wood, all round the trunk, and also the large branches, up to the very top of the tree; the quantity which exudes increasing with the height of the incision. The bleeding may be safely repeated once every fortnight. The fluid, as fresh drawn, is nearly of the consistence of cream, and pure white. Somewhat more than half a *maund* (42 lbs.) is reckoned to be the average produce of each bleeding of one tree; or 20,000 trees will yield about 12,000 maunds of juice: which is composed in 10 parts, of from 4 to 6 parts of water, and, of course, from 6 to 4 parts of caoutchouc. The bleeding should be confined to the cold months, so as not to interfere with or obstruct the vigorous vegetation of the tree in the hot months.

Mr. Griffith says, that the richest juice is obtained from transverse incisions made into the wood of the larger reflex roots, which are half exposed above ground, and that it proceeds from the bark alone. Beneath the line of incisions, the natives of Assam scoop out a hole in the earth, in which they place a leaf of the *Phrynium capitatum* Linn., rudely folded up into the shape of a cup. He observes that the various species of *Tetranthera*, upon which the *Moonga* silkworm feeds, as also the castor oil plant, which is the chief food of the Eria silkworm, do not afford a milky caoutchouc juice. Hence it would appear that Dr. Royle's notion of caoutchouc forming a necessary ingredient in the food of silkworms, and being "in some way employed in giving tenacity to their silk," seems to be unfounded. If Botany discountenances this idea, Chemistry would seem to scout it altogether; for silk contains 11·33 per cent. of azote, and caoutchouc contains none at all; being simply a solid hydro-carburet, and therefore widely dissimilar in constitution to silk, which consists of oxygen 34·04, azote 11·33, carbon 50·69, and hydrogen 3·94 in 100 parts.

This hydro-carburet emulsion is of common occurrence in the ORDERS *Euphorbiacea* and *Tulicea*, which may be looked on as the main sources of caoutchouc. The American caoutchouc is said to be furnished by the *Siphonia elastica*, or the *Hevea guianensis* of Aublet, a tree which grows in Brazil, and also in Surinam.

Dr. Royle sent models of cylinders, of 1½ to 2½ inches in diameter, and 4 or 5 inches in length, to both the Asiatic and Agricultural Societies of Bengal, to serve as patterns for the natives to mould their caoutchouc by. Mr. Griffith says that this plan of forming the caoutchouc into tumblers or bottles, as recommended by the committee of the London Joint Stock Caoutchouc Company, is, in his opinion, the worst that can possibly be offered; being tedious, laborious, causing the caoutchouc to be blackened in the drying, and not obviating the viscidity of the juice when it is exposed to the sun. He recommends, as a far better mode of treating the juice, to work it up with the hands, to blanch it in water, and then subject it to pressure. I shall presently describe a still better method which has recently occurred to me, in experimenting upon the caoutchouc juice. This fluid, with certain precautions, chiefly exclusion from air and much warmth, may be kept in the state of a creamy emulsion for a very long time.

NEW EXPERIMENTAL RESEARCHES ON CAOUTCHOUC.

The specific gravity of the best compact *Para* caoutchouc, taken in dilute alcohol, is - - - - - -	0·941567
The specific gravity of the best Assam is - - -	0·942972
„ „ Sincapore - - -	0.936650
„ „ Penang - - -	0·919178

Having been favoured by Mr. Sievier, formerly managing director of the Joint-Stock Caoutchouc Company, and by Mr. Beale, engineer, with two different samples of caoutchouc juice, I have subjected each to chemical examination.

That of Mr. Sievier is greyish brown, that of Mr. Beale is of a milky grey colour; the deviation from whiteness in each case being due to the presence of aloetic matter, which accompanies the caoutchouc in the secretion by the tree. The former juice is of the consistence of thin cream, has a specific gravity of 1·04125, and yields, by exposure upon a porcelain capsule, in a thin layer, for a few days, or by boiling for a few minutes with a little water, 20 per cent. of solid caoutchouc. The latter, though it has the consistence of pretty rich cream, has a specific gravity of only 1·0175. It yields no less than 37 per cent. of white, solid, and very elastic caoutchouc.

It is interesting to observe how readily and compactly the separate little cloths or threads of caoutchouc coalesce into one spongy mass in the progress of the ebullition, particularly if the emulsive mixture be stirred; but the addition of water is necessary to prevent the coagulated caoutchouc from sticking to the sides or bottom of the vessel and becoming burnt. In order to convert the spongy mass thus formed into good caoutchouc, nothing more is requisite than to expose it to moderate pressure between the folds of a towel. By this process the whole of the aloetic extract, and other vegetable matters, which concrete into the substance of the balls and junks of caoutchouc prepared in Assam and Java, and contaminate it, are entirely separated, and an article nearly white and inodorous is obtained. Some of the cakes of American caoutchouc exhale when cut the fœtor of rotten cheese; a smell which adheres to the threads made of it, after every process of purification.

In the interior of many of the balls which come from both the Brazils and East Indies, spots are frequently found of a viscid tarry-looking matter, which, when exposed to the air, act in some manner as a ferment, and decompose the whole mass into a soft substance, which is good for nothing. Were the plan of boiling the fresh juice along with its own bulk of water, or a little more, adopted, a much purer article would be obtained, and with comparatively less trouble and delay, than has been hitherto brought into the market.

I find that neither of the above two samples of caoutchouc juice affords any appearance of coagulum when mixed in any proportions with alcohol of 0·825 specific gravity; and, therefore, I infer that albumen is not a necessary constituent of the juice, as Mr. Faraday inferred from his experiments published in the 21st vol. of the Journal of the Royal Institution.

The odour of Mr. Sievier's sample is slightly acescent, that of Mr. Beale's, which is by far the richer and purer, has no disagreeable smell whatever. The taste of the latter is at first bland and very slight, but eventually very bitter, from the aloetic impression upon the tongue. The taste of the former is bitter from the first, in consequence of the great excess of aloes which it contains. When the brown solution which remains in the capsule, after the caoutchouc has been separated in a spongy state by ebullition, from 100 grains of the richer juice, is passed through a filter and evaporated, it leaves 4 grains of concrete aloes.

Both of these emulsive juices mix readily with water, alcohol, and pyroxilic spirit, though they do not become at all clearer; they will not mix with *caoutchoucine* (the distilled spirit of caoutchouc), or with petroleum-naphtha, but remain at the bottom of these liquids as distinct as mercury does from water. Soda caustic lye does not dissolve the juice; nitric acid (double aquafortis) converts it into a red curdy magma. The filtered aloetic liquid is not affected by the nitrates of baryta and silver; it affords with oxalate of ammonia minute traces of lime.

I. CAOUTCHOUC MANUFACTURE.

This department of operative industry has, within a few years, acquired an importance equal to that of some of the older arts, and promises, ere long, to rival even the ancient textile fabrics in the variety of its designs and applications. The manufacture of caoutchouc has, at present, three principal branches:—1. The condensation of the crude lumps or shreds of caoutchouc, as imported from South America, India, &c., into compact homogeneous blocks, and the cutting of these blocks into cakes or sheets for the stationer, surgeon, shoemaker, &c. 2. The filature of either the India-rubber bottles, or the artificial sheet caoutchouc, into tapes and threads of any requisite length and fineness, which being clothed with silk, cotton, linen, or woollen yarns, form the basis of elastic tissues of every kind. 3. The conversion of the refuse cuttings and coarser qualities of caoutchouc into a viscid varnish, which, being applied between two surfaces of cloth, constitute the well-known double fabrics, impervious to water and air.

I. The caoutchouc, as imported in skinny shreds, fibrous balls, twisted concretions, cheese-like cakes, and irregular masses, is, more or less, impure, and sometimes fraudulently interstratified with earthy matter. It is cleansed by being cut into small pieces, and washed in warm water. It is now dried on iron trays, heated with steam, while being carefully stirred about to separate any remaining dirt, and is then passed through, between a pair of iron rolls, under a stream of water, whereby it gets a second washing, and becomes at the same time equalized by the separate pieces being blended together. The shreds and cuttings thus laminated, if still foul or heterogeneous, are thrown back into a kind of hopper over the rolls, set one-sixteenth of an inch apart, and passed several times through between them. The above method of preparation is that practised by Messrs. Keene and Co., of Lambeth, in their excellent manufactory, under a patent granted in October, 1836, to Mr. Christopher Nickels, a partner in the firm.

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In the great establishment of the Joint-Stock Caoutchouc Company, at Tottenham, originally under the direction of Mr. Sievier, a gentleman distinguished no less by his genius and taste as a sculptor, than by his constructive talents, the preparatory rinsing and lamination are superseded by a process of washing practised in Mr. Nickels's second operation, commonly called the *grinding*, or, as it should more properly be styled, the *kneading*. The mill employed for agglutinating or incorporating the separate fragments and shreds of caoutchouc into homogeneous elastic ball, is a cylindrical box or drum of cast iron, 8 or 9 inches in diameter, set on its side, and traversed in the line of its horizontal axis (also 8 or 9 inches long) by a shaft of wrought iron, furnished with 3 rows of projecting bars, or kneading arms, placed at angles of 120 deg. to each other. These act by rotation against 5 chisel-shaped teeth, which stand obliquely up from the front part of the bottom of the drum. The drum itself consists of 2 semi-cylinders; the under of which is made fast to a strong iron framing, and the upper is hinged to the under one behind, but bolted to it before, so as to form a cover or lid, which may be opened or laid back at pleasure, in order to examine the caoutchouc from time to time, and take it out when fully kneaded. In the centre of the lid a funnel is made fast, by which the cuttings and shreds of the India rubber are introduced, and a stream of water is made to trickle in, for washing away the foul matter often embedded in it. The power required to turn the axis of one of these mills, as the drums or boxes are called, may be judged of from the fact, that if it be only 2 inches in diameter, it is readily twisted asunder, and requires to be 3 inches to withstand every strain produced by the fixed teeth holding the caoutchouc against the revolving arms. Five pounds constitute a charge of the material.

One of the most remarkable phenomena of the kneading operation, is the prodigious heat disengaged in the alternate condensation and expansion of the caoutchouc. Though the water be cold as it trickles in, it soon becomes boiling hot, and emits copious vapours. When no water is admitted, the temperature rises much higher, so that the elastic lump, though a bad conductor of heat, cannot be safely touched with the hand. As we shall presently find that caoutchouc suffers no considerable or permanent diminution of its volume by the greatest pressure which can be applied, we must ascribe the heat evolved in the kneading process to the violent intestine movements excited throughout all the particles of the elastic mass.

During the steaming much muddy water runs off through apertures in the bottom of the drum. In the course of half an hour's trituration the various pieces become agglutinated into a soft, elastic, ovoid ball, of a reddish brown colour. This ball is now transferred into another similar iron drum, where it is exposed to the pricking and kneading action of 3 sets of chisel points, 5 in each set, that project from the revolving shaft at angles of 120 deg. to each other, and which encounter the resistance occasioned by five stationary chisel teeth, standing obliquely upwards from the bottom of the drum. Here the caoutchouc is kneaded dry along with a little quicklime. It soon gets very hot; discharges in steam through the punctures, the water and air which it had imbibed in the preceding washing operation; becomes in consequence more compact; and in about an hour assumes the dark brown colour of stationers' rubber. During all this time frequent explosions take place, from the expansion and sudden extrication of the imprisoned air and steam.

From the second set of drums the ball is transferred into a third set, whose revolving shaft being furnished both with flat pressing bars, and parallel sharp chisels, perpendicular to it, exercises the twofold operation of pricking and kneading the mass, so as to condense the caoutchouc into a homogeneous solid. Seven of these finished balls, weighing as above stated, 5 pounds each, are then introduced into a much larger iron drum of similar construction, but of much greater strength, whose shaft is studded all round with a formidable array of blunt chisels. Here the separate balls become perfectly incorporated into one mass, free from honeycomb cells or pores, and therefore fit for being squeezed into a rectangular or cylindrical form in a suitable cast-iron mould, by the action of a screw-press. When condensed to the utmost in this box, the lid is secured in its place by screw-bolts, and the mould is set aside for several days. It is a curious fact, that Mr. Sievier has tried to give this moulding force, by the hydraulic press, without effect, as the cake of caoutchouc, after being so condensed, resiles much more considerably than after the compressing action of the screw. The cake form generally preferred for the recomposed, ground, or milled caoutchouc, is a rectangular mass, about 18 inches long, 9 inches broad, and 5 inches thick.

This is sliced into cakes for the stationer, and into sheets for making tapes and threads of caoutchouc, by an ingenious self-acting machine, in which a straight steel blade with its edge slanting downwards, is made to vibrate most rapidly to and fro in a horizontal plane; while the cake of caoutchouc clamped or embraced at each side between two strong iron bars, is slowly advanced against the blade by screw-work like that of the slide-rest of a lathe. In cutting caoutchouc by knives of every form, it is essential that either the blade or the incision be constantly moistened with water; for otherwise the tool would immediately stick fast. As the above straight vibrating knife slants obliquely downwards, the sheet which it cuts off spontaneously turns up over the blade in proportion as it is detached from the bottom mass of the cake. The thicker slices are afterwards cut by hand, with a wetted knife, into small parallelopipeds for the stationer, the sections being guided rectangularly by saw lines in a wooden frame. The wholesale price of these is now reduced to 2*s.* per pound. Slices may be cut off to almost any desired degree of thinness, by means of an adjusting screw—a mechanism that acts against a board which supports the bottom of the cake, and raises it by any aliquot part of an inch, the cutting blade being caused to vibrate always in the same horizontal plane. These thin slices constitute what is called sheet caoutchouc, and they serve tolerably for making tubes for pneumatic apparatus, and sheaths of every kind; since, if their two edges be cut obliquely with clean scissors, they may be made to coalesce, by gentle pressure, so intimately that the line of junction cannot be discovered either by the eye, or by inflation of a bag or tube thus formed.

The mode of recomposing the cuttings, shreds, and coarse lumps of caoutchouc, into a homogeneous elastic cake, specified by Mr. Nickels, for his patent, sealed October 24, 1836, is not essentially different from that above described. The cylinders of his mill are more capacious, are open at the sides like a cage, and do not require the washing apparatus, as the caoutchouc has been cleansed by previous lamination and rinsing. He completes the kneading operation, in this open cylinder, within the space of about two hours, and afterwards squeezes the large ball so formed into the cheese form, in a mould subjected to the action of an hydraulic press. As he succeeds perfectly in making compact cakes in this way, his caoutchouc must differ somewhat in its physical constitution from that recomposed by Mr. Sievier's process. He uses a press of the power of 70 tons; such pressure, however, must not be applied suddenly, but progressively, at intervals of two or three minutes between each stroke; and when the pressing is complete, he suffers the caoutchouc to remain under pressure till it is cold, when he thrusts it out of the mould entirely, or, placing his mould in the slide-rest mechanism, he gradually raises the caoutchouc out of it, while the vibrating knife cuts it into slices in the manner already described. The elegant machine by which these sheets are now so easily and accurately sliced, was, I believe, originally contrived and constructed by Mr. Beale, engineer, Church-lane, Whitechapel.

II. FILATURE OF CAOUTCHOUC FOR MAKING ELASTIC FABRICS.

Messrs. Rattier and Guibal mounted in their factory at St. Denys, so long ago as the year 1826 or 1827, a machine for cutting a disc of caoutchouc into a continuous fillet spirally, from its circumference towards its centre. This flat disc was made by pressing the bottom part of a bottle of India-rubber in an iron mould. I have described this machine under the article Elastic Bands. A machine on the same principle was made the subject of a patent by Mr. Joshua Proctor Westhead, of Manchester, February 16, 1836; and, being constructed with the well-known precision of Manchester workmanship, it has been found to act perfectly well in cutting a disc of caoutchouc, from the circumference towards the centre spirally, into one continuous length of tape. For the service of this machine, the bottom of a bottle of India-rubber of good quality being selected, is cut off and flattened by heat and pressure into a nearly round cake of uniform thickness. This cake is made fast at its centre by a screw nut and washer to the end of a horizontal shaft, which may be made to revolve with any desired velocity by means of appropriate pulleys and bands, at the same time that the edge of the disc of caoutchouc is acted on by a circular knife of cast steel, made to revolve 3000 times per minute, in a plane at right angles to that of the disc, and to advance upon its axis progressively, so as to pare off a continuous uniform tape or fillet from the circumference of the cake. During this cutting operation, the knife and caoutchouc are kept constantly moist with a slender stream of water. A succession of threads of any desired fineness is afterwards cut out of this fillet, by drawing it in a moist state through a guide slit, against the sharp edge of a revolving steel disc. This operation is dexterously performed by the hands of young girls. MM. Rattier and Guibal employed, at the above-mentioned period, a mechanism consisting of a series of circular steel knives, fixed parallel to each other at minute distances, regulated by interposed washers upon a revolving shaft; which series of knives acted against another similar series, placed upon a parallel adjoining shaft, with the effect of cutting the tape throughout its length into eight or more threads at once. An improved modification of that apparatus is described and figured in the specification of Mr. Nickels's patent of October, 1836. He employs it for cutting into threads the tapes made from the recomposed caoutchouc.

The body of the bottle of India-rubber, and in general any hollow cylinder of caoutchouc, is cut into tapes, by being first forced upon a mandril of soft wood of such dimensions as to keep it equally distended. This mandril is then secured to the shaft of a lathe, which has one end formed into a fine-threaded screw, that works in a fixed nut, so as to traverse from right to left by its rotation. A circular disc of steel, kept moist, revolves upon a shaft parallel to the preceding, at such a distance from it as to cut through the caoutchouc, so that, by the traverse movement of the mandril shaft, the hollow cylinder is cut spirally into a continuous fillet of a breadth equal to the thickness of the side of the cylinder. Mr. Nickels has described two methods of forming hollow cylinders of recomposed caoutchouc, for the purpose of being cut into fillets by such a machine.

It is probable that the threads formed from the best India-rubber bottles, as imported from Para, are considerably stronger than those made from recomposed caoutchouc, and therefore much better adapted for making Mr. Sievier's patent elastic cordage. When, however, the kneading operation has been skilfully performed, I find that the threads of the *ground* caoutchouc, as it is incorrectly called by the workmen, answer well for every ordinary purpose of elastic fabrics, and are, of course, greatly more economical, from the much lower price of the material.

Threads of caoutchouc are readily pieced by paring the broken ends obliquely with scissors, and then pressing them together with clean fingers, taking care to admit no grease or moisture within the junction line. These threads must be deprived of their elasticity before they can be made subservient to any torsile or textile manufacture. Each thread is *inelasticated* individually in the act of reeling, by the tenter boy or girl pressing it between the moist thumb and finger, so as to stretch it to at least eight times its natural length, while it is drawn rapidly through between them by the rotation of the power-driven reel. This extension is accompanied with condensation of the caoutchouc, and with very considerable disengagement of heat, as pointed out in Nicholson's Journal upwards of 30 years ago, by Mr. Gough, the blind philosopher of Kendal. I attempted to stretch the thread, in the act of reeling, but found the sensation of heat too painful for my unseasoned fingers. The reels, after being completely filled with the thread, are laid aside for some days, more or fewer, according to the quality of the caoutchouc, the recomposed requiring a longer period than the bottle material. When thus rendered inelastic, it is wound off upon bobbins of various sizes, adapted to various sizes of braiding, or other machines, where it is to be clothed with cotton or other yarn.

In the process of making the ELASTIC TISSUES, the threads of caoutchouc being first of all deprived of their elasticity, are prepared for receiving a sheath upon the braiding machine. For this purpose they are stretched by hand, in the act of winding upon the reel, to 7 or 8 times their natural length, and left two or three weeks in that state of tension upon the reels. Thread thus *inelasticated* has a specific gravity of no less than 0·948732; but when it has its elasticity restored, and its length reduced to its pristine state, by rubbing between the warm palms of the hands, the specific gravity of the same piece of thread is reduced to 0·925939. This phenomenon is akin to that exhibited in the process of wire-drawing, where the iron or brass gets condensed, hard, and brittle, while it disengages much heat; which the caoutchouc thread also does in a degree intolerable to unpractised fingers, as above mentioned.

The thread of the Joint-Stock Caoutchouc Company is numbered from 1 to 8. No. 1. is the finest, and has about 5000 yards in a pound weight; No. 4. has 2000 in the pound weight; and No. 8. 700, being a very powerful thread. The finest is used for the finer elastic tissues, as for ladies' gold and silver elastic bracelets and bands. The ropes made by Mr. Sievier with the strongest of the above threads, clothed with hemp and worked in his gigantic braiding machine, possess, after they are re-elasticated by heat, an extraordinary strength and elasticity; and, from the nearly rectilinear direction of all the strands, can stand, it is said, double the strain of the best patent cordage of like diameter.

In treating of the manufacture of elastic fabrics, I have great pleasure in adverting to the ribbon looms at Holloway, which display to great advantage the mechanical genius of the patentee, Mr. Sievier. Their productive powers may be inferred from the following statement:—5000 yards of 1-inch braces are woven weekly in one 18 ribbon loom, whereby the female operative, who has nothing to do but watch its automatic movements, earns 10*s.* a-week; 3000 yards of 2-inch braces are woven upon a similar loom in the same time. But one of Mr. Sievier's most curious patent inventions is, that of producing, by the shrinking of the caoutchouc threads in the foundation or warp of the stuff, the appearance of raised figures, closely resembling coach-lace, in the weft. Thus, by a simple physical operation, there is produced, at an expense of one penny, an effect which could not be effected by mechanical means for less than one shilling.

III. OF THE WATER-PROOF DOUBLE FABRICS.

The parings, the waste of the kneading operations above described, and the coarsest qualities of imported caoutchouc, such as the inelastic lumps from Para, are worked up into varnish, wherewith two surfaces of cloth are cemented, so as to form a compound fabric, impervious to air and water. The caoutchouc is dissolved either in petroleum (coal-tar), naphtha, or oil of turpentine, by being triturated with either of the solvents in a close cast-iron vessel, with a stirring apparatus, moved by mechanical power. The heat generated during the attrition of the caoutchouc, is sufficient to favour the solution, without the application of fuel in any way. These triturating cylinders have been called pug-mills by the workmen, because they are furnished with obliquely pressing and revolving arms, but in other respects they differ in construction. They are 4 feet in diameter and depth, receive 13 cwt. at a time, have a vertical revolving shaft of wrought iron 4 inches in diameter, and make one turn in a second. Three days are required to complete the solution of one charge of the varnish materials. The proportion of the solvent oils varies with the object in view, being always much less in weight than the caoutchouc.

When the varnish is to be applied to very nice purposes, as bookbinding, &c., it must be rubbed into a homogeneous smooth paste, by putting it in a hopper, and letting it fall between a couple of parallel iron rolls, set almost in contact.

The wooden frame-work of the gallery in which the water-proof cloth is manufactured, should be at least 50 yards long, to give ample room for extending, airing, and drying the pieces; it should be 2 yards wide, and not less than 5 high. It is formed of upright standards of wood, bound with three or four horizontal rails at the sides of the ends. At the end of the gallery, where the varnish is applied, the web which is to be smeared must be wound upon a beam resembling in size and situation the cloth beam of the weaver's loom. This piece is thence drawn up and stretched in a horizontal direction over a bar, like the breast beam of a loom, whence it is extended in a somewhat slanting direction downwards, and passed over the edge of a horizontal bar. Above this bar, and parallel to it, a steel-armed edge of wood is adjusted, so closely as to leave but a narrow slit for the passage of the varnish and the cloth. This horizontal slit may be widened or narrowed at pleasure by thumb-screws, which lower or raise the movable upper board. The caoutchouc paste being plastered thickly with a long spatula of wood upon the down-sloped part of the web, which lies between the breast-beam and the above described slit, the cloth is then drawn through the slit by means of cords in a horizontal direction along the lowest rails of the gallery, whereby it gets uniformly besmeared. As soon as the whole web, consisting of about 40 yards, is thus coated with the viscid varnish, it is extended horizontally upon rollers, in the upper part of the gallery, and left for a day or two to dry. A second and third coat are then applied in succession. Two such webs, or pieces, are next cemented face to face, by passing them, at the instant of their being brought into contact, through between a pair of wooden rollers, care being taken by the operator to prevent the formation of any creases, or twisting of the twofold web. The under one of the two pieces being intended for the lining, should be a couple of inches broader than the upper one, to insure the uniform covering of the latter, which is destined to form the outside of the garment. The double cloth is finally suspended in a well-ventilated stove-room, till it becomes dry, and nearly free from smell. The parings cut from the broader edges of the under piece, are reserved for cementing the seams of cloaks and other articles of dress. The tape-like shreds of the double cloth are in great request among gardeners, for nailing up the twigs of wall shrubs.

Mr. Walton, of Sowerby-bridge, has recently substituted sheet India-rubber for leather, in the construction of fillet cards for the cotton and tow manufactures. The superior elasticity of this article is said to prove advantageous in several respects.

Mr. Charles Keene, proprietor of the extensive and well-organized India-rubber factory in Lambeth, obtained a patent in March, 1840, for applying a coat of caoutchouc to the outer surface of flexible leather. The varnish of caoutchouc, made with oil of turpentine, has so much lampblack incorporated with it, as to bring it to the consistence of dough. The edge of the doe-skin, buck-skin, and wash-leather, being introduced between a pair of wetted iron rollers, as much of the India-rubber compound, softened by a gentle heat, and rolled into a proper length as will cover the leather, is laid in the hollow between the leather and the moist cylinders. By their rotation, the coating is evenly effected. When the surface has become dry, it may be embossed or gilt, and varnished over with a solution of shellac, with a little Venice turpentine, in alcohol. After two or three applications of this kind, the leather is passed through a pair of iron rollers, either smooth or embossed. When made up articles, such as shoes or portmanteaus, &c., are to be covered, the India-rubber varnish is used in a thinner state.—*Newton's Journal*, xxiii. 357.

Caoutchouc sulphured.—Mr. Burke in describing his patented process for vulcanizing India-rubber, says, that he avoids two principal defects of the usual article, viz. its efflorescence of sulphur with an offensive odour, and its consequent decomposition and becoming rotten. He employs crude antimony (the sulphuret of that metal in fine powder), and converts it by boiling in water with soda or potash (carbonates) into the orange sulphuret of that metal (Kermes mineral) by the addition of hydrochloric acid to the fluid in slight excess. He combines this compound (after being well washed) with caoutchouc or gutta percha, either together or separately, according to the degree of elasticity which he wishes to obtain. This mixture is afterwards subjected to a heat of from 250° to 280° Fahr. He masticates the caoutchouc in the usual iron box, by means of the kneading fluted revolving rollers, subjecting the whole to heat. The antimonial compound is then added in quantities varying from 5 to 15 lbs., according to the strength and elasticity required in the compound. At the end of from one to two hours' trituration, the block is removed from the box, and while in a warm state it is strongly compressed in an iron mould; and after being under pressure for a day or two is subjected to a steam heat for a couple of hours. The block thus prepared may now be cut into sheets, and afterwards divided into threads, or formed into such other articles as are desired.

The patentee also mixes the flock of silk, cotton or wool, with liquefied caoutchouc, and applies this compound for waterproofing cloth, previously coated with the ordinary water-proof composition. He also proposes to strengthen the gutta percha bands for driving-pulleys by affixing strips of leather to their edges; and to apply metal tips or shields to the gutta percha heels and soles of boots and shoes.

The clamminess of Caoutchouc is removed by Mr. Hancock in the following manner: 10 pounds of it are rolled out into a thin sheet between iron cylinders, and at the same time 20 pounds of French-chalk (silicate of magnesia) are sifted on and incorporated with it, by means of the usual kneading apparatus. When very thin films are required (like sheets of paper) the caoutchouc, made plastic with a little naphtha, is spread upon cloth previously saturated with size, and when dry is stripped off. Mixtures of caoutchouc so softened may be made with asphalt, with pigments of various kinds, plumbago, sulphur, &c.

The improvements patented in January, 1849, by Mr. Christopher Nickels, consist—1. In a modification of the grinding, kneading or masticating machine, by furnishing its roller with flanges at its two ends to prevent the rubber from coming against the ends of the cylinder. When sulphur is to be kneaded into it in the process of vulcanizing the rubber, as it is called, he covers in the trough, but not otherwise. He has also given an excentric action to his roller.

He kneads with his rubber flowers of sulphur, or compounds thereof, in the proportion of 10 pounds of sulphur to 60 pounds of caoutchouc, and he subjects the compound to pressure in moulds. He prefers to treat the caoutchouc with the fumes of sulphur, or gases containing sulphur, in order to make a combination in the kneading cylinder. He uses a retort to distil the vapour of sulphur upon the rubber in the cylinder heated in a steam jacket. He also occasionally introduces hydrogen or phosphorus along with it. The compound mass thus obtained is to be subjected to hydraulic pressure, in the moulds, heated to about 220° or 250° Fahr. He causes the blocks to undergo a rolling motion under heavy pressure by machinery; the effect of which motion is to equalize the sulphur diffused in the blocks. Even thread of the ordinary India-rubber, when agitated in a box with flowers of sulphur, is said to be glazed and improved thereby. —*Newton's Journal*, xxxv. 21.

The porosity of caoutchouc explains the readiness with which it is permeated by different liquids which have no chemical action upon it. Thin sections of dry caoutchouc of the best kinds absorb from 18 to 26 per cent. of water in the course of a month, and become white from having been brown. The best solvent is a mixture of 100 parts of sulphuret of carbon with from 6 to 8 parts of anhydrous alcohol. If the alcohol be mixed with a little water a dough is obtained, from which the caoutchouc may be drawn out into threads and spun. By Gerard's process, gutta percha is also soluble in the above mixtures of sulphuret of carbon and alcohol.

The sulphuration of caoutchouc, a valuable invention, is due to Mr. Charles Goodyear of New York. The process of cold sulphuring of Mr. Parkes consists in plunging the sheets or tubes of caoutchouc in a mixture of 100 parts of sulphuret of carbon, and 2½ parts of protochloride of sulphur, for a minute or two, and then immersing them in cold water. Thus supersulphuration is prevented in consequence of decomposing the chloride of sulphur on the surface by this immersion, while the rest of the sulphur passes into the interior by absorption. Mr. Parkes prescribes another, and perhaps a preferable process, which consists in immersing the caoutchouc in a closed vessel for 3 hours, containing a solution of polysulphuret of potassium indicating a density of 25° Beaumé, at the temperature of 248° Fahr., then washing in an alkaline solution, and lastly in pure water. A uniform impregnation is thus obtained.

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CAPERS, are plucked before they open, and thrown into strong vinegar slightly salted, where they are pickled. The crop of each day is added to the same vinegar tub, so that in the course of the six months during which the caper shrub flowers, the vessel gets filled, and is sold to persons who sort the capers (the smallest being most valued) by means of copper sieves. This metal is attacked by the acid, wherefrom the fruit acquires a green colour, much admired by *ignorant connoisseurs.*

CAPSTAN. (*Cabestan*, Fr.; *Spille*, Germ.) A machine whereon the cable is wound successively in weighing the anchor of a vessel. It is a species of wheel and axle; the axle being vertical, and pierced with holes near its top for the insertion of the ends of horizontal levers, called handspikes, which represent the wheel. These are turned by the force of men moving in a circle. The power applied to the lever is to the resistance to be overcome, (the weight of the anchor, for example,) when the forces are in equilibrio, as the radius of the cylinder round which the cable is coiled is to the circumference described by the power. It is manifest that the radius of the axle must be augmented in this computation by half the diameter of the cable, which is supposed to lie always one coil thick upon it. The force of a man, thus applied, has been commonly estimated as equal to the traction of 27 pounds hanging over a pulley. Friction being so variable a quantity in capstans, renders the exact calculation of its mechanical effect somewhat uncertain. A stout man, stationed near the bottom of the axle, holds fast the loose part of the cable, which has already made two or three turns; and, being aided by its friction upon the wood, he both prevents it from slipping backwards, and uncoils each turn as it is progressively made.

Mr. Hindmarsh, master mariner of Newcastle, obtained a patent, in February, 1827, for a contrivance to enable a capstan or windlass to be occasionally worked with increased mechanical advantage. With this view, he placed toothed wheel-work, partly in the drum-head of the capstan, and partly in the upper part of the barrel, upon which the cable is coiled and uncoiled in successive portions.

The drum-head, and also the barrel, turn loosely upon a central spindle, independent of each other, and are connected together either by the toothed gear, or by bolts. On raising or withdrawing the connecting pinion from the toothed wheels, and then locking the drum-head and barrel together, the capstan works with a power equal only to that exerted by the men at the capstan-bars, as an ordinary capstan; but on lowering the pinion into gear with the wheel-work, and withdrawing the bolts which locked the drum-head to the barrel, the power exerted by the men becomes increased in proportion to the diameter and numbers of teeth in the wheels and pinions.

Fig. 322 is the external appearance of this capstan. *Fig*. 323 a horizontal view of the toothed gear at the top of the barrel. The barrel, with the whelps *a a*, turns loosely upon a vertical spindle fixed into the deck of the vessel. The drum-head *b* also turns loosely upon the same spindle. The circular frame *c c*, in *fig*. 323 in which the axes of the toothed wheels *d d d* are mounted, is fixed to the central spindle. The rim *e e e*, with internal teeth, is made fast to the top of the barrel; and the pinion *f*, which slides upon the spindle, is connected to the drum-head.

When it is intended to work the capstan with ordinary power, the pinion *f* is raised up into the recess of the drum-head, by means of a screw g, *fig*. 322, which throws it out of gear with the toothed wheels, and it is then locked up by a pin *z*: the bolts *h h* are now introduced, for the purpose of fastening the drum-head and barrel together, when it becomes an ordinary capstan.

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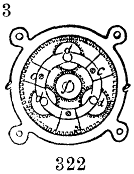

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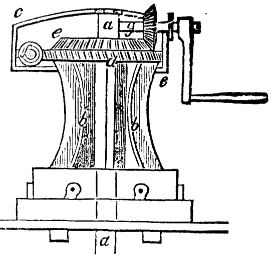

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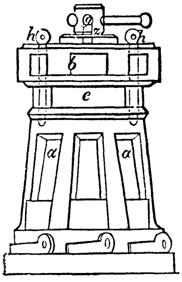

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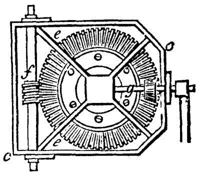


But when it is required that the same number of men shall exert a greater power, the bolts *h* are withdrawn, and the pinion *f* lowered into gear with the toothed wheels. The rotation of the drum-head, then carrying the pinion round, causes it to drive the toothed wheels *d d d*; and these working into the toothed rim *e e*, attached to the barrel, cause the barrel to revolve with an increased power.

Thus, under particular circumstances, a smaller number of men at the capstan or windlass (which is to be constructed upon the same principle) will be enabled to haul in the cable and anchor, or warp off the vessel, which is an important object to be effected.

In 1819, Captain Phillips obtained a patent for certain improvements in capstans, a part of which invention is precisely the same as this in principle, though slightly varied in its adaptation.

James Brown, ship-rigger, in his capstan, patented in 1833, instead of applying the moving power by handspikes, having fixed two rims of teeth round the top of the capstan, acts upon them by a rotatory worm, or pinions turned by a winch.

Fig. 324 is an elevation of this capstan, and *fig.* 325 is a horizontal top view: *a* is an upright shaft, fixed firmly to the deck, serving as an axle round which the body of the capstan revolves. A frame *c*, fixed to the top of a stationary shaft *a*, above the body of the capstan, carries the driving apparatus.

The upper part of the body of the capstan has a ring of oblique teeth *d* formed round its edge; and above this, on the top of the capstan, is a ring of bevel teeth *e*. A horizontal shaft *f*, mounted in the top frame *c*, has a worm or endless screw, which takes into the teeth of the ring *d;* and a short axle *g*, having its bearings in the central shaft *a*, and in the frame *c*, carries a bevel pinion, which takes into the bevel teeth of the ring *e*.

The bearings of the shaft *f*, in the top frame, are in long slots, with angular returns, something like the fastening of a bayonet, which is for the purpose of enabling the shaft to be readily lifted in and out of gear with the teeth of the ring *d:* the outer bearing of the axle *g* of the bevel pinion is also supported in the frame *c*, in a similar way, in order to put it in and out of gear with the teeth of the bevel ring *e*. A mode of shifting these is essential; because the two toothed rings, and their driving worm and pinion, give different speeds, and, of course, cannot be both in operation at the same time.

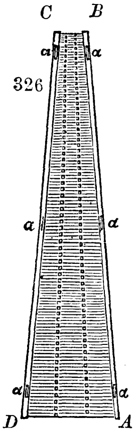
The worm of the shaft *f*, being placed in gear with the teeth of the ring *d*, on applying rotatory power thereto, by means of winches attached to the ends of the shaft, the barrel or body of the capstan will be made to revolve with a slow motion, but with great power; and thus two men at the winches will do the same work as many men with capstan bars in the ordinary way.

If a quicker movement than that of the endless screw is desired, then the driving power may be applied by a winch to the axle *g* of the bevel pinion, that pinion being put into gear with the bevel ring *e*, and the endless screw withdrawn. It should, however, be here remarked, that the patentee proposes to employ two short axles *g*, placed opposite to each other, with bevel pinions acting in the bevel-toothed ring, though only one is shown in the figure, to avoid confusion. He also contemplates a modification of the same contrivance, in which four short axles *g*, placed at right angles, with pinions taking into a bevel ring, may be employed, and made effective in giving rotatory motion to the barrel of a capstan by means of winches applied to the outer ends of the axle, and turned by the labor of four men.

CARAT, or CARACT, is a weight used by goldsmiths and jewellers. See Assay and Diamond.

CARBON (*Carbone*, Fr.; *Kohlenstoff*, Germ.), in a perfectly pure state, constitutes diamond. Carbonaceous substances are usually more or less compound, containing hydrogen, or sometimes oxygen, and azote, along with earthy and metallic matters. Carbon, tolerably pure, abounds in the mineral kingdom; and, in a combined state, it forms a main constituent of vegetable and animal bodies. Anthracite is a mineral charcoal, differing from common pit-coal in containing no bitumen, and therefore burning without flame or smoke. *Coke* is the carbonaceous mass which remains after pit-coal has been exposed to ignition for some time out of contact of air; its volatile parts having been dissipated by the heat. It is a spongy substance, of an iron-black color, a somewhat metallic lustre, and does not easily burn unless several pieces are kindled together. With a good draught, however, it produces a most intense heat. *Wood charcoal* is obtained by the calcination of wood in close vessels, as described under the article Acetic Acid, or in piles of various shapes, covered with loam, to screen it from the free action of the atmosphere, which would otherwise consume it entirely. See Charcoal. Such carbon is a solid, without smell or taste, and bears the strongest heats of our furnaces without suffering any change, provided air be excluded: it is a bad conductor of heat, but conducts electricity very well. When burned, it unites with oxygen, and forms carbonic acid, the fixed air of Dr. Black, the choke-damp of the miner. When this carbonic acid is made to traverse red hot charcoal it dissolves a portion of it, and becomes carbonic oxyde, which contains only one half of its volume of oxygen; whereas carbonic acid consists of one volume of oxygen combined with one volume of the vapor of carbon, the two being condensed into one volume. If the specific gravity of oxygen, = 1·1025, be deducted from that of carbonic acid, = 1·5245, the difference, = 0·422, will be the specific gravity of the vapor of carbon; as well as the proportion present in that weight of the acid.

Charcoal obtained by the action of a rapid fire in close vessels is not so solid and so good a fuel as that which is made in the ancient way by the slow calcination of pyramidal piles covered with earth. One of the most economical ovens for making wood charcoal is that invented by M. Foucauld, which he calls a *shroud*, or *abri*. To construct one of these, 30 feet in diameter at the base, 10 feet at its summit, and from 8 to 9 feet high, he forms, with wood 2 inches square, a frame 12 feet long, 3 feet broad at one end, and one foot at the other. The figure will explain the construction. The uprights, A B and C D, of this frame are furnished with three wooden handles *a a a*, and *a′ a′ a′*, by means of which they can be joined together, by passing through two contiguous handles a wooden fork, the frame being previously provided with props, as shown in *fig.* 326, and covered with loam mixed with grass. A flat cover of 10 feet diameter, made of planks well joined, and secured by four cross bars, is mounted with two trap doors, M N, *fig.* 328, for giving egress to the smoke at the commencement of the operation; a triangular hole P, cut out in the cover, receives the end of a conduit Q R S, (*figs.* 329 and 328,) of wood formed of three deals, destined to convey the gases and condensed liquids into the casks F G H. Lastly, a door T, which may be opened and shut at pleasure, permits the operator to inspect the state of the fire. The charcoal calcined by this *abri*, has been found to be of superior quality.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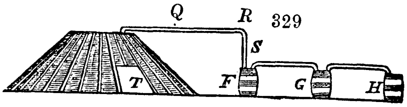
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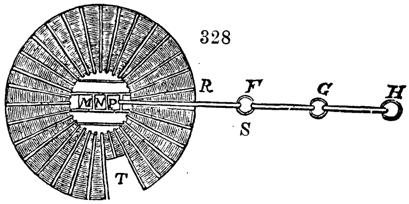
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When it is wished to change the place where the *abri* is erected, and to transport it to a store of new-felled timber, the frame is taken down, after beating off the clay which covers it, the joints are then cut by a saw, as well as the ends of the forks which fixed the frames to one another. This process is economical in use, simple and cheap in construction; since all the pieces of the apparatus are easily moved about, and may be readily mounted in the forests. For obtaining a compact charcoal, for the use of artisans, this mixed process of Foucauld is said to be preferable to either the close iron cylinder or the pile.

For making gunpowder-charcoal the lighter woods, such as the willow, dogwood, and alder answer best; and in their carbonization care should be taken to let the vapors freely escape, especially towards the end of the operation, for when they are re-absorbed, they greatly impair the combustibility of the charcoal.

By the common process of the forests, about 18 per cent. of the weight of the wood is obtained; by the process of Foucauld about 24 per cent. are obtained, with 20 of crude pyroligneous acid of 10 degrees Baumé. By the process described under Acetic Acid, 27 of charcoal, and 18 of acid at 6 degrees, are procured from 100 parts of wood, besides the tar. These quantities were the results of careful experimenting, and are greater than can be reckoned upon in ordinary hands.

Charcoal for chemical purposes may be extemporaneously prepared by calcining pieces of wood covered with sand in a crucible, till no more volatile matter exhales.

The charcoal of some woods contains silica, and is therefore useful for polishing metals. Being a bad conductor of heat, charcoal is employed sometimes in powder to incase small furnaces and steam-pipes. It is not affected by water; and hence the extremities of stakes driven into moist ground are not liable to decomposition. In like manner casks when charred inside preserve water much better than common casks, because they furnish no soluble matter for fermentation or for food to animalcules.

Lowitz discovered that wood charcoal removes offensive smells from animal and vegetable substances, and counteracts their putrefaction. He found the odor of succinic and benzoic acids, of bugs, of empyreumatic oils, of infusions of valerian, essence of wormwood, spirits distilled from bad grain, and sulphureous substances were all absorbable by freshly calcined charcoal properly applied. A very ingenious filter has been constructed for purifying water, by passing it through strata of charcoal of different fineness.

When charcoal is burned, one third of the heat is discharged by radiation, and two thirds by conduction.

The following table of the quantity of charcoal yielded by different woods was published by Mr. Mushet, as the result of experiments carefully made upon the small scale. He says, the woods before being charred were thoroughly dried, and pieces of each kind were selected as nearly alike in every respect as possible. One hundred parts of each sort were taken, and they produced as under:—

Lignum Vitæ afforded	26·0	of charcoal of a grayish color, resembling coke.
Mahogany - - -	25·4	tinged with brown, spongy and porous.
Laburnum - -	24·5	velvet black, compact, very hard.
Chestnut - - -	23·2	glossy black, compact, firm.
Oak - - - -	22·6	black, close, very firm.
Walnut - - -	20·6	dull black, close, firm.
Holly - - -	19·9	dull black, loose and bulky.
Beech - - -	19·9	dull black, spongy, firm.
Sycamore - -	9·7	fine black, bulky, moderately firm.
Elm - - -	9·5	fine black, moderately firm.
Norway Pine - -	19·2	shining black, bulky, very soft.
Sallow - - -	18·4	velvet black, bulky, loose and soft.
Ash - - -	17·9	shining black, spongy, firm.
Birch - - -	17·4	velvet black, bulky, firm.
Scottish Pine - -	16·4	tinged with brown, moderately firm.

Messrs. Allen and Pepys, from 100 parts of the following woods, obtained the quantities of charcoal as under:—

Beech - - -	15·00	Oak - - -	17·40
Mahogany - -	15·75	Fir - - - -	18·17
Lignum Vitæ - -	17·25	Box - - -	20·25

It is observable that the quantities obtained by Messrs. Allen and Pepys are in general less than those given by Mr. Mushet, which may be owing to Mr. Mushet not having applied sufficient heat, or operated long enough, to dissipate the aqueous matter of the gaseous products.

To those persons who buy charcoal by weight, it is important to purchase it as soon after it is made as possible, as it quickly absorbs a considerable portion of water from the atmosphere. Different woods, however, differ in this respect. Messrs. Allen and Pepys found, that by a week's exposure to the air, the charcoal of

Lignum Vitæ gained -	9·6	per cent.
Fir - - - - -	13·0	ditto.
Box - - - - -	14·0	ditto.
Beech - - - -	16·3	ditto.
Oak - - - - -	16·5	ditto.
Mahogany - - -	18·0	ditto.

The following is a tabular view of the volumes of the different gases which were absorbed in the course of 24 hours, by one volume of charcoal, in the experiments of M. Theodore de Saussure, which were conducted in a way likely to produce correct results. Each portion of charcoal was heated afresh to a red heat, and allowed to cool under mercury. When taken from the mercury, it was instantly plunged into the vessel of gas:

Ammoniacal gas - -	90	Bicarbureted hydrogen -	35·00
Muriatic acid gas - -	85	Carbonic oxyde - -	9·42
Sulphurous acid - -	65	Oxygen gas - - -	9·25
Sulphureted hydrogen -	55	Nitrogen - - -	7·50
Nitrous oxyde - - -	40	Carbureted hydrogen -	5·00
Carbonic acid gas - -	35	Hydrogen gas - -	1·75

Neumann, who made many experiments on charcoal, informs us, that for the reduction of the metallic oxydes, the charcoal of the heavier woods, as that of the oak and the beech, is preferable, and that, for common fuel, such charcoal gives the greatest heat, and requires the most plentiful supply of air to keep it burning; while those of the lighter woods preserve a glowing heat with a much less draught of air; and that for purposes where it is desirable to have a steady and a still fire, charcoal should be employed which has been made from wood previously divested of its bark, since it is the cortical part which crackles and flies off in sparks during combustion, while the coal of the wood itself seldom does.

For making crayons of charcoal, the willow is the best wood that can be employed, as the softness is uniform in all its parts. Its durability may be seen in several of our old churchyards, where the letters made with lamp-black are still perfect, though the white lead with which the body of the stones was painted is entirely destroyed.

This property of carbon is shown, however, in a more striking manner by the writings that were found in the ruins of Herculaneum, which have retained their original blackness for two thousand years. The ancients wrote with ink made from ground charcoal.

If it be required to purify any carbonaceous matter, to render it fitter for delicate pigments, this may be done by first calcining it in a close vessel, and then lixiviating it in water slightly acidulated by nitric acid.

The incorruptibility of charcoal was well known to the ancients, and they availed themselves of this property upon all important occasions.

About sixty years ago a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes to prevent the passage of Julius Cæsar and his army. These stakes were charred to a considerable depth, had retained their form completely, and were firm at the heart.

Most of the houses in Venice stand upon piles of wood, which have all been previously charred for their preservation. In this country, estates were formerly marked out by charred stakes driven to a considerable depth into the ground. See Bone-black, Charcoal, and Graphite.

CARBONATED WATER is water either pure, or holding various saline matters in solution, impregnated with carbonic acid gas. For general sale in this country, the water usually contains a little soda, which being charged with the gas, is called *Soda water;* see this article for a description of an excellent machine for the manufacture of this fashionable beverage.

CARBONATES. Saline compounds in definite proportions of carbonic acid, with alkalis, earths, and the ordinary metallic oxydes.

The carbonates principally used in the arts and manufactures are those of *ammonia, copper, iron, lead, lime, magnesia, potash, soda.* Native carbonate of copper is the beautiful green mineral called Malachite.

Carbonates are easily analyzed by estimating either by weight or measure the quantity of carbonic acid which they evolve under the decomposing action of somewhat dilute sulphuric, nitric, or muriatic acid; for as they are all compounds of acid, and base in equivalent proportions, the quantity of acid will indicate the quantity of base. Thus, as pure limestone consists of 56 of lime and 44 of acid, in 100 parts, if upon examining a sample of limestone we find it to give out only 22 per cent. of carbonic acid gas, during its slow solution in muriatic acid, we are sure that there are only 28 parts of lime present. I have described, in the Annals of Philosophy for October, 1817, a simple form of apparatus for analyzing the carbonates with equal readiness and precision. The simple rule by *measure* to which I was led, may be thus stated: *From the bulk of evolved gas, expressed in cubic inches and tenths, deduct* $\frac{1}{20}$, *the remainder will express the proportion of real limestone present in the grains employed.* Pure magnesian limestone yields very nearly a cubic inch of the gas for every grain in weight.

CARBONATE OF AMMONIA. A salt called in modern chemistry *sesqui-carbonate*, to denote its being composed of one and a half equivalent primes of carbonic acid, and one of ammonia. It consists by my analysis of 55·89 carbonic acid, 28·86 ammonia, and 15·25 water, in 100 parts. It is generally prepared by mixing from $1\frac{1}{4}$ to $1\frac{1}{2}$ parts of well-washed dry chalk, with 1 of sal-ammoniac, introducing the mixture into an earthen or cast-iron retort, or subliming pot, and exposing it to a heat gradually raised to redness. By double decomposition, the ammonia is volatilized in combination with the carbonic acid of the chalk, and the vapors are received in a condensing receiver made either of glass, stone ware, or lead. The chlorine of the sal-ammoniac remains in the retort, associated with the basis of the chalk in the state of chloride of calcium. Some ammonia gas escapes during the process.

The saline mass thus sublimed is purified by a second sublimation in glass or salt-glazed earthen vessels. The salt may be obtained, by the above method carefully conducted, in rhomboidal octahedrons, but it is generally made for the market in a compact semi-crystalline white cake. It has a pungent ammoniacal smell; a hot, pungent, alkaline taste; a strong alkaline reaction, and dissolves in two parts of cold water. It must be kept in well-closed vessels, as by exposure to the air a portion of its ammonia exhales, and it passes into the state of the scentless bi-carbonate. It is employed much in medicine, chemical analysis, and by the pastry-cooks to give sponginess to their cakes, in consequence of its volatilization from their dough in the oven. See Sal-Ammoniac.

For the other carbonates used in the arts, see their respective bases; copper, lead, lime, &c.

CARBONIC ACID (*Acide carbonique*, Fr.; *Kohlensaure*, Germ.) consists of 1 prime equivalent of carbon=6·125+2 of oxygen=16·026, whose joint sum=22·151, represents the atomic weight or combining ratio of this acid, in the neutral or protocarbonate salts. Its composition by volume is stated under Carbon. Its natural form is a gas, whose specific gravity is 1·5245, compared to atmospheric air 1·000; and being so dense, it may be poured out of one vessel into another. Hence it was called at first *aërial acid.* From its existing copiously, in a solid state, in limestones and the mild alkalis, it was styled *fixed air* by its proper discoverer, Dr. Black. About one volume of it exists in 1000 volumes of common atmospheric air, which may be made manifest by the crust of carbonate it occasions upon the surface of lime water. Carbonic acid gas is found accumulated in many caverns of volcanic districts, and particularly in the *grotto dei cani* at Pausilippo, near Puzzuoli; being disengaged in such circumstances by the action of subterranean fire, and, possibly, of certain acids, upon the limestone strata. It often issues from fountains in copious currents, as at Franzensbrunn, near Eger, in Polterbrunnen; near Trier; and Byrreshorn. This acid gas occurs also frequently in mines and wells, being called *choke damp*, from its suffocating quality. Its presence may, at all times, be detected, by letting down a lighted candle, suspended from a string, into the places suspected of containing this mephitic air. It exists, in considerable quantities, in the water of every pump well, and gives it a fresh and pleasant taste. Water, exposed some time to the air, loses these aerial particles, and becomes vapid. Many springs are highly impregnated with carbonic acid gas, and form a sparkling beverage; such as the *Selterswasser*, from Selters upon the Lahn, in the grand dutchy of Nassau; of which no less than two millions and a half of bottles are sold every year. A prodigious quantity of a similar water is also artificially prepared in Great Britain, and many other countries, under the name of aërated or soda water.

Carbonic acid occurs in nature, combined with many salifiable bases; as in the carbonates of soda, baryta, strontia, magnesia; the oxydes of iron, manganese, zinc, copper, lead, &c. From these substances it may be separated, generally speaking, by strong ignition, or, more readily, by the superior affinity of muriatic, sulphuric, or nitric acid, for the earth or metallic oxyde. It is formed whenever vegetable or animal substances are burned with free access of air, from the union of their carbonaceous principle with atmospheric oxygen. It is also formed in all cases of the spontaneous decomposition of organic substances, particularly in the process of fermentation; and constitutes the pungent, noxious, heavy gas thrown off, in vast volumes, from beer vats. See Distillation and Fermentation. Carbonic acid is also generated in the breathing of animals; from 4 to 5 per cent., in volume, of the inhaled oxygen being converted, at each expiration, into this gas, which contaminates the air of crowded apartments, and renders ventilation essential to health, and even to life; witness the horrible catastrophe of the Black-hole at Calcutta.

Carbonic acid gas is destitute of color, has a sourish, suffocating smell, an acidulous pungent taste, imparts to moist, but not dry, litmus paper, a transient reddish tint, and weighs per 100 cubic inches, 46½ grains; and per cubic foot, 803½ grains; a little more than 3¾ oz. avoirdupoise. A cubic foot of air weighs about two thirds of that quantity, or 527 grains. It may be condensed into the liquid state by a pressure of 40 atmospheres, and this liquid may be then solidified by its own sudden spontaneous evaporation. If air contain more than 15 per cent. in bulk of this gas, it becomes unfit for respiration and combustion, animal life and candles being speedily extinguished by it.

Before a person ventures into a deep well, or vault containing fermenting materials, he should introduce a lighted candle into the space, and observe how it burns. Carbonic acid, being so much denser than common air, may be drawn out of cellars or fermenting tubs, by a pump furnished with a leather hose, which reaches to the bottom. Quicklime, mixed with water, may be used also to purify the air of a sunk apartment, by its affinity for, or power of, absorbing this aërial acid. See Mineral Waters and Soda Water.

CARBONIC OXYDE. See the article Carbon.

CARBUNCLE. A gem highly prized by the ancients; most probably a variety of the noble garnet of modern mineralogists.

CARBURET OF SULPHUR, called also sulphuret of carbon, and alcohol of sulphur, is a limpid volatile liquid possessing a penetrating fetid smell, and an acrid burning taste. Its specific gravity is 1·265; and its boiling point is about 112° Fahr. It evaporates so readily, and absorbs so much heat in the vaporous state, that if a tube containing quicksilver, surrounded with lint dipped in this liquid, be suspended in the receiver of an air-pump on making the vacuum, the quicksilver will be congealed. It consists of 15·8 carbon and 84·2 sulphur, in 100 parts; being two equivalent primes of the latter to one of the former.

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CARBURETED HYDROGEN. A compound of carbon and hydrogen, of which there are several species—such as oil-gas, coal-gas; olefiant gas, oil of lemons, otto of roses, oil of turpentine, petroleum, naptha, napthaline, oil of wine, caoutchoucine, and caoutchouc.

CARDS, PLAYING. (*Cartes à jouer*, Fr.; *Karten*, Germ.) Mr. de la Rue obtained, in February, 1832, a patent for certain improvements in the manufacture of playing cards, which he distributed under three heads; first, printing the pips, and also the picture or court cards, in oil colors by means of types or blocks; secondly, effecting the same in oil colors by means of lithography; and thirdly, gilding or silvering borders, and other parts of the characters, by the printing process, either by types, blocks, or lithography.

In the ordinary mode of manufacturing playing cards, their devices are partly produced by copperplate printing, and they are filled up with water colors by the means called stencilling.

The patentee does not propose any material alteration in the devices or forms upon the cards, but only to produce them with oil colors; and, to effect this, he follows precisely the same mode as that practised by calico printers.

A set of blocks or types properly devised, are produced for printing the different pips of hearts, diamonds, spades, and clubs, or they are drawn, as other subjects, in the usual way upon stone. The ink or color, whether black or red, is to be prepared from the best French lamp-black, or the best Chinese vermilion ground in oil, and laid on the types and blocks, or on the stone, in the same way as printers' ink, and the impressions taken-on to thick drawing paper by means of a suitable press in the ordinary manner of printing.

The picture or court-cards are to be produced by a series of impressions in different colors, fitting into each other exactly in the same way as in printing paper hangings, or silks and calicoes, observing that all the colors are to be prepared with oil.

For this purpose a series of blocks or types are to be provided for each subject, and which, when put together, will form the whole device. These blocks are to be used separately, that is, all the yellow parts of the picture, for instance, are to be printed at one impression, then all the red parts, next all the flesh color, then the blue portions, and so on, finishing with the black outlines, which complete the picture.

If the same is to be done by lithography, there must be as many stones as there are to be colors, each to print its portion only; and the impression, or part of the picture given by one stone, must be exactly fitted into by the impression given from the next stone, and so on until the whole subject is complete.

A superior kind of card is proposed to be made, with gold or silver devices in parts of the pictures, or gold or silver borders round the pips. This is to be effected by printing the lines which are to appear as gold or silver, with gilders' size, in place of ink or color; and immediately after the impression has been given, the face of the card is to be powdered over with gold dust, silver, or bronze, by means of a soft cotton or wool dabber, by which the gold, silver, or bronze will be made to adhere to the picture, and the superfluous portions of the metal will wipe off by a very slight rubbing. When the prints are perfectly dry, the face of the card may be polished by means of a soft brush.

If it should be desirable to make these improved cards to resemble ivory, that may be done by preparing the face of the paper in the first instance with a composition of size and fine French white, and a drying oil, mixed together to about the consistency of cream; this is to be washed over the paper, and dried before printing, and when the cards are finished they will exactly resemble ivory.

The only thing remaining to be described, is the means by which the successive impressions of the types, blocks, or stones, forming the parts of the pictures, are to be brought exactly to join each other, so as to form a perfect whole design when complete; this is by printers called registering, and is to be effected much in the usual way, by points in the tympan of the press, or by marks upon the stones.

The parts of the subject having been all accurately cut or drawn to fit, small holes are to be made with a fine awl through a quire or more of the paper at once, by placing upon the paper a gauge-plate, having marks or guide-holes, and by observing these, the same sheet laid on several times, and always made to correspond with the points or marks, the several parts of the picture must inevitably register, and produce a perfect subject.

CARD CUTTING. Mr. Dickinson's patent machine for cutting cards, consists of a pair of rollers with circular revolving cutters, the edges of which are intended to act against each other as circular shears, and the pasteboards in passing between these rollers are cut by the circular shears into cards of the desired dimensions. These rollers are mounted in suitable standards, with proper adjustments, and are made to revolve by a band and pulley connected to the axle of a crank, or by any other convenient means.

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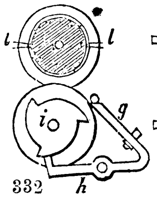

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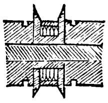

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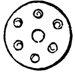

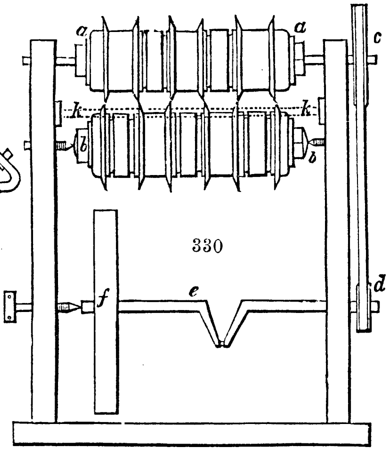

Fig. 330 is a front view of this machine; *a a* and *b b* are the two rollers, the upper one turning upon an extended axle, bearing in the standards, the lower one upon pivots. These rollers are formed by a series of circular blocks, between a series of circular steel cutters, which are slidden on to iron shafts, and held together upon their axle by nuts screwed up at their ends. The accurate adjustment of the cutters is of the first importance to their correct performance; it is therefore found necessary to introduce spiral springs within the blocks, in order to press the cutters up to their proper bearings. A section of one of the blocks is shown at *fig.* 332, and an end view of the same at *fig.* 333, with the spiral springs inserted.

At the outer extremity of the axle of the roller *a*, a rigger *c*, is attached, whence a band passes to a pulley *d*, on the crank shaft *e*, to which a fly-wheel *f*, is affixed, for the purpose of rendering the action uniform. Rotatory motion being given to the crank shaft, the upper roller is turned, the lower roller moving at the same time by the friction against the edges of the cutters.

Fig. 331 is an end view of the rollers, showing the manner in which the pasteboards are guided and conducted between the cutters. In the front of the machine a moveable frame *g*, is to be placed, for the purpose of receiving the pasteboards, preparatory to cutting them into cards, and a stop is screwed to this frame for the edge of the pasteboard to bear against, which stop is adjustable to suit different sizes. From the back part of this frame an arm *h*, extends, the extremity of which acts against the periphery of a ratchet wheel *i*, fixed at the end of the roller *b*, and hence, as the roller goes round, the frame is made to rise and fall upon its pivots, for the purpose of guiding the pasteboard up to the cutters; at the same time a rod *k*, hanging in arms from the sides of the standards (shown by dots in *fig.* 330), falling upon the pasteboard, confines it, while the cutters take hold, and racks corresponding with the indentations of the rollers are placed as at *l l*, by means of which the cards, when cut, are pushed out of the grooves.

As various widths of cards will require to be cut by this machine, the patentee proposes to have several pairs of rollers ready adjusted to act together, when mounted in the standards, in preference to shifting the circular cutters, and introducing blocks of greater or less width.

The second part of the invention is a machine for pasting the papers, and pressing the sheets together to make pasteboard. This machine consists of several reels (we suppose rollers are intended) on which the paper is to be wound, along with a paste trough, and rotatory brushes. The several parts of this machine, and their operations in making pasteboard, are described in the specification, but the patentee having omitted the letters of reference in the drawing which he has enrolled, it becomes difficult to explain it.

As far as we are enabled to understand the machine, it appears, that damped paper is to be wound upon two rollers, and conducted from thence over two other rollers; that two fluted rollers revolving in the paste trough are to supply paste to two circular brushes, and that by those brushes the papers are to be pasted upon one side, and then pressed together, to make the pasteboard; after this, the pasteboard is to be drawn on to a table, and to remain there until sufficiently dry to be wound upon other rollers. By comparing this description with the figure, perhaps the intended operations of the machine may be discovered: it is the best explanation we are enabled to give.

CARDS (*Cardes*, Fr.; *Karden*, Germ.) are instruments which serve to disentangle the fibres of wool, cotton, or other analogous bodies, to arrange them in an orderly lap or fleece, and thereby prepare them for being spun into uniform threads. The fineness and the leveiness of the yarn, as well as the beauty of the cloth into which it enters, depend as much upon the regularity and perfection of the carding, as upon any subsequent operations of the factory. The quality of the carding depends more upon that of the cards than upon any attention or skill in the operative; since it is now nearly an automatic process, conducted by young women called card-tenters.

Cards are formed of a sheet or fillet of leather pierced with a multitude of small holes, in which are implanted small staples of wire with bent projecting ends called *teeth*. Thus every piece of wire is double toothed. The leather is afterwards applied to a flat or cylindrical surface of wood or metal, and the co-operation of two or more such surfaces constitutes a card. The teeth of cards are made thicker or slenderer, according as the filaments to be carded are coarser or finer, stiffer or more pliant, more valuable or cheaper. It is obviously of great importance that the teeth should be all alike, equably distributed, and equally inclined over the surface of the leather, a degree of precision which is scarcely possible with handwork. To judge of the difficulty of this manipulation we need only inspect the annexed figures. The wire must first be bent at right angles in *c* and *d*, *fig.* 335, then each branch must receive a second bend in *a* and *b* at a determinate obtuse angle, invariable for each system of cards. It is indispensable that the two angles *c a e* and *d b f* be mathematically equal, not only as to the twin teeth of one staple, but through the whole series; for it is easy to see that if one of the teeth be more or less sloped than its fellow, it will lay hold of more or less wool than it, and render the carding irregular. But though the perfect regularity of the teeth be important, it is not the sole condition towards making a good card. It must be always kept in view that these teeth are to be implanted by pairs in a piece of leather, and kept in it by the cross part *c d*. The leather must therefore be pierced with twin holes at the distance *c d*; and pierced in such a manner, that the slope of the holes, in reference to the plane of the leather, be invariably the same; for otherwise the length of the teeth would vary with this angle of inclination, and the card would be irregular.

A third condition essential towards producing perfect regularity, is that the leather ought to be of the same thickness throughout its whole surface, otherwise the teeth, though of the same length and fixed at the same angle, would be rendered unequal by the different thicknesses of the leather, and the operation of carding would be in consequence extremely defective. *Fig.* 334 shows the card teeth acting against each other, as indicated by the arrows in two opposite directions; in *fig.* 336 they work one way.

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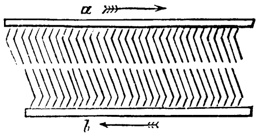

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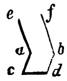

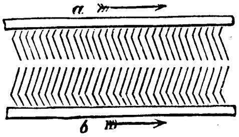

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Of late years very complex but complete and well-acting machines have been constructed for splitting the leather or equalizing it by shaving, for bending and cutting the wires, and implanting them in the leather, into holes pierced with perfect regularity. Card machines which fashion the teeth with great precision and rapidity, and pierce the leather, have been for a considerable time in use at Halifax, in Yorkshire, a town famous for the excellence of its card-cloth, as also at Leeds, Glasgow, and several other places. The wires and the leather thus prepared are given out by the manufacturer to women and children, who put them together.

1. The simplest machine for equalizing the leather which can be employed, is that which I saw operating in MM. Scrive's automatic card factory at Lille, the most magnificent I believe in the world, where the leather was drawn forwards by a roller over a solid horizontal table, or bed, and passed under a nicely adjusted vertical blade, which shaved it by a scraping motion to a perfectly uniform thickness. About one half the weight of the leather is lost in this process, and in the subsequent squaring and trimming.

The machine for making cards, invented I believe by a Mr. Ellis of the United States, for which a first patent was obtained in this country by Joseph Cheeseborough Dyer, Esq. of Manchester, in 1811, and a second and third with further improvements in 1814, and 1824, is one of the most elegant automatons ever applied to productive industry. It is, however, necessarily so complicated with different mechanisms as to render its representation impracticable in such engravings as are compatible with the scope of this dictionary. I must therefore content myself with the following general description of its constituent parts.

The first thing to be done after having, as above, prepared the long sheets or fillets of leather of suitable length, breadth, and thickness, for making the cards, is to stretch the leather, and hold it firmly; which is accomplished by winding the fillet of leather upon the roller or drum, like the warp roller of a loom, and then conducting it upwards between guide rollers, to a receiving or work roller at top of the machine, where the fillet is held fast by a cramp, by which means the leather is kept stretched.

Secondly, the holes are pierced in the leather to receive the wire staples or teeth of the card, by means of a sliding fork, the points of which are presented to the face of the leather; while the fork is made to advance and recede continually, by the agency of levers worked by rotatory cams upon a revolving main shaft.

The points of the fork being thus made to penetrate into the leather, the holes for receiving the staples are pierced at regular distances, and in correct order, by shifting the leather fillet so as to bring different parts of its surface opposite to the points of the sliding fork. This is done by cams, or indented wheels and gear, which shift the guide rollers and confining drums laterally, as they revolve, and consequently move the fillet of leather at intervals a short distance, so as to present to the points of the fork or piercer, at every movement, a different part of the surface of the leather.

Thirdly, the wire of which the teeth or points of the card are to be made, is supplied from a coil on the side of the machine, and is brought forward at intervals by a pair of sliding pincers, which are slidden to and fro through the agency of levers actuated by rotatory cams upon the main shaft. The pincers having advanced a distance equal to the length of wire intended to form one staple or two points, this length of wire is pressed upon exactly in the middle by a square piece of steel, and being there confined, a cutter is brought forward, which cuts it off from that part of the wire held in the pincers.

The length of wire thus separated and confined is now, by a movement of the machine, bent up along the sides of the square steel holder, and shaped to three edges of the square, that is, formed as a staple; and in the same way, by the continued movements of the machine, a succession of pieces of wire are cut off, and bent into staples for making the teeth of the card as long as the mechanism is kept in action.

Fourthly, the wire staple thus formed is held with its points or ends outwards, closely contiguous to the forked piercer described above, and by another movement of the mechanism, the staple is protruded forward, its end entering into the two holes made previously in the leather by the sliding of the fork.

While the wire staple is being thus introduced into the leather, its legs or points are to be bent, that is, formed with a knee or angle, which is the fifth object to be effected. This is done by means of a small apparatus consisting of a bar or bed, which bears up against the under side of the wire staple when it has been passed half way into the holes in the leather, and another bar above it, which, being brought down behind the staple, bends it over the resisting bar to the angle required; that is, forms the knee in each leg. A pusher now acts behind the staple, and drives it home into the leather, which completes the operation.

The leather being thus conducted, and its position shifted before the piercer progressively, a succession of the above described operations of cutting the wire, forming the staple, passing it into the leather, and bending its legs to the angular form, produces a sheet of card of the kind usually employed for carding or combing wool, cotton, and other fibrous materials. It may be necessary to add, that as these wire staples are required to be set in the leathers sometimes in lines crossing the sheet, which is called ribbed, and at other times in oblique lines, called twilled, these variations are produced by the positions of the notches or steps upon the edge or periphery of the cam or indented wheel, which shifts the guide rollers that hold the fillet or sheet of leather as already described.

CARMINE (Eng. and Fr.; *Karminstoff*, Germ.) is, according to Pelletier and Caventou, a triple compound of the coloring substance, and an animal matter contained in cochineal, combined with an acid added to effect the precipitation. The preparation of this article is still a mystery, because, upon the one hand, its consumption being very limited, few persons are engaged in its manufacture, and upon the other, the raw material being costly, extensive experiments on it cannot be conveniently made. Success in this business is said to depend not a little upon dexterity of manipulation, and upon knowing the instant for arresting the further action of heat upon the materials.

There is sold at the shops different kinds of carmine, distinguished by numbers, and possessed of a corresponding value. This difference depends upon two causes; either upon the proportion of alumina added in the precipitation, or of a certain quantity of vermilion put in to dilute the color. In the first case the shade is paler, in the second it has not the same lustre. It is always easy to discover the proportion of the adulteration. By availing ourselves of the property of pure carmine to dissolve in water of ammonia, the whole foreign matter remains untouched, and we may estimate its amount by drying the residuum.

To make Ordinary Carmine.

Take 1 pound of cochineal in powder;
3 drachms and a half of carbonate of potash;
8 drachms of alum in powder;
3 drachms and a half of fish-glue.

The cochineal must be boiled along with the potash in a copper containing five pailsful of water (60 pints); the ebullition being allayed with cold water. After boiling a few minutes the copper must be taken from the fire, and placed on a table at such an angle as that the liquor may be conveniently transvased. The pounded alum is then thrown in, and the decoction is stirred; it changes color immediately, and inclines to a more brilliant tint. At the end of fifteen minutes the cochineal is deposited at the bottom, and the bath becomes as clear as if it had been filtered. It contains the coloring matter, and probably a little alum in suspension. We decant it then into a copper of equal capacity, and place it over the fire, adding the fish-glue dissolved in a great deal of water, and passed through a searce. At the moment of ebullition, the carmine is perceived to rise up to the surface of the bath, and a coagulum is formed, like what takes place in clarifications with white of egg. The copper must be immediately taken from the fire, and its contents be stirred with a spatula. In the course of fifteen or twenty minutes the carmine is deposited. The supernatant liquor is decanted, and the deposite must be drained upon a filter of fine canvass or linen. If the operation has been well conducted, the carmine, when dry, crushes readily under the fingers. What remains after the precipitation of the carmine is still much loaded with color, and may be employed very advantageously for carminated lakes. See LAKE.

By the *old German process*, carmine is prepared by means of alum without any other addition. As soon as the water boils, the powdered cochineal is thrown into it, stirred well, and then boiled for six minutes; a little ground alum is added, and the boiling is continued for three minutes more; the vessel is removed from the fire, the liquor is filtered and left for three days in porcelain vessels, in the course of which time a red matter falls down, which must be separated and dried in the shade. This is carmine, which is sometimes previously purified by washing. The liquor after three days more lets fall an inferior kind of carmine, but the residuary coloring matter may also be separated by the muriate of tin.

The proportions for the above process are 580 parts of clear river water, 16 parts of cochineal, and 1 part of alum; there is obtained from 1½ to 2 parts of carmine.

Another *carmine with tartar.*—To the boiling water the cochineal is added, and after some time a little cream of tartar; in eight minutes more we add a little alum, and continue the boiling for a minute or two longer. Then take it from the fire and pour it into glass or porcelain vessels, filter, and let it repose quietly till the carmine falls down. We then decant and dry in the shade. The proportions are 8 pounds of water, 8 oz. of cochineal, ½ oz. of cream of tartar, ¾ oz. of alum, and the product is an ounce of carmine.

The process of Alxon or Langlois.—Boil two pails and a half of river water (30 pints), throw into it, a little afterwards, a pound of cochineal, add a filtered solution of six drachms of carbonate of soda and a pound of water, and let the mixture boil for half an hour; remove the copper from the fire, and let it cool, inclining it to one side. Add six drachms of pulverized alum, stir with a brush to quicken the solution of the salt, and let the whole rest 20 minutes. The liquor, which has a fine scarlet color, is to be carefully decanted into another vessel, and there is to be put into it the whites of two eggs well beat up with half a pound of water. Stir again with a brush. The copper is replaced on the fire, the alumina becomes concrete, and carries down the coloring matter with it. The copper is to be taken from the fire, and left at rest for 25 or 30 minutes to allow the carmine to fall down. When the supernatant liquor is drawn off, the deposite is placed upon filter cloth stretched upon a frame to drain. When the carmine has the consistence of cream cheese, it is taken from the filter with a silver or ivory knife and set to dry upon plates covered with paper, to screen it from dust. A pound of cochineal gives in this way an ounce and a half of carmine.

Process of Madame Cenette, of Amsterdam, with salt of sorrel.—Into six pails of river water boiling hot throw two pounds of the finest cochineal in powder, continue the ebullition for two hours, and then add 3 oz. of refined saltpetre, and after a few minutes 4 oz. of salt of sorrel. In ten minutes more take the copper from the fire and let it settle for four hours; then draw off the liquor with a syphon into flat plates and leave it there for three weeks. Afterwards there is formed upon the surface a pretty thick mouldiness, which is to be removed dexterously in one pellicle by a slip of whalebone. Should the film tear and fragments of it fall down, they must be removed with the utmost care. Decant the supernatant water with a syphon, the end of which may touch the bottom of the vessel, because the layer of carmine is very firm. Whatever water remains must be sucked away by a pipette. The carmine is dried in the shade, and has an extraordinary lustre.

Carmine by the salt of tin, or the Carmine of China.—Boil the cochineal in river water, adding some Roman alum, then pass through a fine cloth to remove the cochineal, and set the liquor aside. It becomes brighter on keeping. After having heated this liquor, pour into it, drop by drop, solution of tin till the carmine be precipitated. The proportions are one pailful of water, 20 oz. of cochineal, and 60 grains of alum, with a solution of tin containing 4 oz. of the metal.

To revive or brighten carmine.—We may brighten ordinary carmine, and obtain a very fine and clear pigment, by dissolving it in water of ammonia. For this purpose we leave ammonia upon carmine in the heat of the sun, till all its color be extracted, and the liquor has got a fine red tinge. It must be then drawn off and precipitated, by acetic acid and alchohol, next washed with alcohol, and dried. Carmine dissolved in ammonia has been long employed by painters, under the name of liquid carmine.

Carmine is the finest red color which the painter possesses. It is principally employed in miniature painting, water colors, and to tint artificial flowers, because it is more transparent than the other colors. For *Carminium*, see COCHINEAL.

This valuable pigment is often adulterated with starch. Water of ammonia enables us to detect this fraud by dissolving the pure carmine, and leaving the starchy matter, as well as most other sophisticating substances. Such debased carmine is apt to spoil with damp.

CARPET. (*Tapis*, Fr.; *Teppich*, Germ.) A thick woollen fabric of variegated colors, for covering the floors of the better sort of apartments. This luxurious manufacture took its origin in Persia and Turkey, whence the most beautiful patterns were wont to come into Europe; but they have been for some time surpassed by the workmanship of France, Great Britain, and Belgium. To form a just conception of the elegant and ingenious processes by which carpets are made, we should visit the royal establishment of the Gobelins at Paris, where we would see the celebrated carpet manufactory of the Savounerie, which has been transported thither. A detailed set of engravings of this art is given by Roland de la Platière in the first and second volumes of the Encyclopédie Méthodique, to which I must refer my readers, as a due exposition of its machines and operations would far exceed the scope of the present volume.

The warp, says M. Roland, being the foundation of the fabric, ought to be of fine wool, equally but firmly spun, and consist of three yarns twisted into one thread. The yarns that are to form the velvety surface of the carpet, ought also to be of the best quality, but soft and downy in their texture, so that the dye may penetrate every filament. Hemp, or linen yarns, are likewise employed in this manufacture, as a woof, to bind the warp firmly together after each shoot of the velvety threads. Thus we see that good carpeting consists essentially of two distinct webs woven at the same time, and firmly decussated together by the woof threads. Hence the form of the pattern is the same upon the two sides of the cloth, only the colors are reversed, so that what was green upon one side becomes red or black upon the other, and *vice versa*. The smaller the figures the more frequent the decussations of the two planes, and the firmer and more durable the fabric.

The carpet manufacture, as now generally practised, may be distributed into two systems—that of double fabrics, and that cut in imitation of velvet. Of late years the Jacquard loom has been much used in weaving carpets, the nature of which will be found fully explained under that title.

For the sake of illustration, if we suppose the double carpets to be composed of only two colors, the principle of weaving will be easily understood; for it is only necessary to raise the warp of each web alternately for the passage of the shuttle, the upper web being entirely above when the under web is being woven, or decussated, and *vice versa*. In a Brussels carpet the worsted yarn raised to form the pile, and make the figure, is not cut; in the Wilton the pile is cut to give it a velvety aspect and softness. In the imperial Brussels carpet the figure is raised above the ground, and its pile is cut, but the ground is uncut; and in the royal Wilton, the pile is both raised higher than in the common Wilton, and it is cut, whereby it has a rich cushion-like appearance. The cloth of all these superior carpets consists of woollen and linen, or hemp; the latter being put upon a beam, and brought, of course, through heddles and a reed; but as its only purpose is to bind together the worsted fabric, it should not be visible upon the upper face of the carpet. The worsted yarn is wound upon small bobbins or pirns, with a weight affixed to each, for giving proper tension to the threads. Their number varies, for one web, from 1300 to 1800, according as the carpet is to be 27 or 36 inches wide; and they are placed, in frames, behind the loom, filled with differently colored yarn, to correspond with the figure. This worsted warp is then drawn through the harness, heddles, and reed, to be associated with the linen yarn in the compound fabric.

In Kidderminster carpeting, both warp and weft appear upon the face of the cloth, whereas, in the Brussels style, only the warp is seen, its binding weft being fine hempen or linen threads. The three-ply imperial carpet, called the Scotch, is coming very much into vogue, and is reckoned by many to be little inferior in texture, look, and wear to the Brussels. Kilmarnock has acquired merited distinction by this ingenious industry. In this fabric, as well as in the two-ply Kidderminster, the weft predominates, and displays the design; but in the French carpets, the worsted warp of the web shows the figure. Plain Venetian carpets, as used for stairs and passages, are woven in simple looms, provided merely with the common heddles and reed. The warp should be a substance of worsted yarn, so heavy as to cover in the weft completely from the view Figured Venetian carpets are woven in the two-ply Kidderminster looms, and are provided with a mechanism to raise the pattern upon the worsted warp. The weft is an alternate shoot of worsted and linen yarn, and must be concealed.

The following figure and description will explain the construction of the three-ply imperial Scotch and two-ply Kidderminster carpet-loom, which is merely a modification of the Jacquard *métier*. The Brussels carpet-loom, on the contrary, is a draw-boy loom on the damask plan, and requires the weaver to have an assistant. *Fig.* 337, A A A, is the frame of the loom, consisting of four upright posts, with caps and cross rails to bind them together. The posts are about six feet high. C C, the cloth-beam, is a wooden cylinder, six inches or thereby in diameter, of sufficient length to traverse the loom, with iron gudgeons in the two ends, which work in bushes in the side frame. On one end of this beam is a ratchet wheel, with a teeth to keep it from turning round backwards by the tension of the web. D, the lay, with its reed, its under and upper shell, its two lateral rulers or swords, and rocking-tree above. There are grooves in the upper and under shell, into which the reed is fitted. E, the heddles, or harness, with a double neck attached to each of the tower or card mechanisms F F, of the Jacquard loom. The heddles are connected and work with the treddles B B, by means of cords, as shown in the figure. G G are wooden boxes for the cards. H, the yarn or warp-beam.

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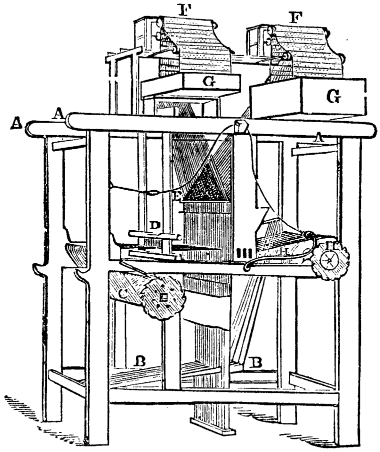

In draw-looms of every kind, there is no sinking of any portion of the warp, as in plain cloth-weaving; but the plane of the warp is placed low, and the threads under which the shuttle is to pass are raised, while all the rest remains stationary. The harness part of this carpet-loom is moved by an assistant boy or girl, who thus allows the weft to be properly decussated, while the weaver attends to working the front mounting or heddles. *Fig.* 338, A represents the frame of a carpet draw-loom; B is a box or frame of pulleys, over which the cords of the harness pass, and are then made fast to a piece of wood, seen at E, which the weavers call a table. From the tail of the harness the simples descend, and to the end of each is attached a small handle G, called a bob. These handles being disposed in pairs, and their regularity preserved by means of a perforated board C, it is merely necessary to pull every handle in succession; the weaver, at the same time, working his treddles with his feet, as in any other loom. The treddles are four in number, the fabric being that of plain or alternate cloth, and two treddles allotted for each web. The harness part of the carpet draw-loom is furnished with *mails*, or metallic eyes, to save friction; two threads being drawn through each eye. The design or pattern of a carpet is drawn upon cross-rule paper, exactly in the same way as every other kind of fancy-loom work, and is transferred from the paper to the mounting by the rules for damask weaving. Suppose that a double web is so mounted that every alternate thread of the one may be raised, so as to form a sufficient shed-way for the shuttle, without depressing the other in the least. Then suppose another web placed above the former, at such a distance that it will exactly touch the convexity of those threads of the former which are raised. Then, if the threads of the latter web are sunk while the others are raised, the two would be entirely incorporated. But if this be only partially done, that is, at particular places, only those parts immediately operated upon will be affected by the action of the apparatus. If the carpet is a two-colored pattern, as black and red, and if upon the upper sur

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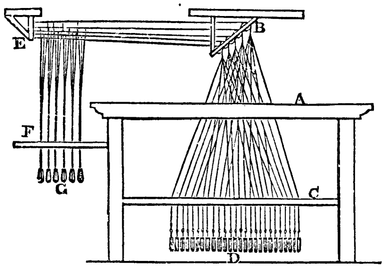

face, as extended in the loom, red flowers are to be represented upon a black ground, then all those species of design paper which are colored may be supposed to represen the red, and those which are vacant the black. Then counting the spaces upon the paper, omit those which are vacant, and cord those which are colored, and the effect will be produced. But as the two webs are to be raised alternately, whatever is corded for the first handle must be passed by for the second, and *vice versa ;* so that the one wi form the flower, and the other the ground.

The board by which the simples are regulated appears at F. D shows the weights.

CARPET—New Patent. Mr. Simcox, of Kidderminster, has patented an invention for an improved manufacture of carpets, in which, by dispensing with the Jacquard loom, as well as the iron wires and tags usually employed to produce terry fabrics, such as Brussels carpets and coach-lace, he can work his machinery at greater speed and more economically. His second improvement relates to the manufacture of fabrics with cut pile, such as Wilton or Axminster carpets. He makes a ribbed fabric, greatly resembling the Brussels carpet, by a combination of woollen and linen warp and weft, arranged in such a manner that the woollen warp, in the form of a ribbed surface, may constitute the face of the fabric, while the linen warp forms the ground or back of the fabric. The plan he prefers, as most resembling the Brussels, consists in weaving the fabric as nearly as possible in the ordinary way, except that, instead of inserting a tag or wire to form the rib or terry, the patentee throws in a thick shoot or weft of woollen or cotton, over which the woollen warp is drawn, and forms a rib; the woollen warp being afterwards bound down with a linen shoot or weft in the ordinary way. The woollen warp employed being all of one colour, the fabric produced will be plain or unornamented, with a looped or terry pile; and upon this fabric any design may be printed from blocks.

The looms differ from the former chiefly in the employment of two separate shuttles, one for the woollen and one for the linen weft. These shuttles are both thrown by the same pickers and the same picking-sticks, and consequently the shuttle boxes must be moved up and down as may be required, in order to allow the picker to throw the proper shuttle. It will also be necessary to work the healds in a suitable manner to form the proper shreds, in order that the woollen face may be properly bound to the linen ground.

Figures illustrating the construction of his loom are given by the patentee.

The second part of his invention relates to the production of fabrics with a cut pile, like the Axminster or Wilton rugs or carpets. The ordinary mode of making some of these fabrics is to weave the pattern in by means of a Jacquard apparatus, and pass the woollen warp over a rod or tag, which is afterwards cut by passing a suitable knife along it, thereby producing the cut pile. The patentee produces the design and surface of the fabric from the weft in place of the warp as heretofore. For this purpose the weft is made to consist of thick woollen shoots, which must be painted or stained with suitable colours, precisely as the woollen warps have been heretofore done; and the woollen shoot, when thrown in, is, by means of suitably formed hooks, pulled up and turned into loops, which, when they are properly secured to the foundation or ground of the fabric, are afterwards cut by means of knives or cutting instruments, with which the hooks are furnished, for the purpose of releasing them from the loops, and producing the cut pile. The patentee observes, that cotton and other cheap materials may be employed with great advantage in the production of some of these fabrics.—*Newton's Journal*, xxxiv. 167.

Another invention of improvements in manufacturing figured fabrics, principally designed for the production of carpeting, patented by Mr. James Templeton, of Glasgow, consists in producing the pattern either on one or both sides of the fabric, by means of printed weft; also in the use of printed parti-coloured fur or weft, in the manufacture of Axminster carpet, and other similar fabrics. This invention is also applicable to the production of figured chenille weft for the manufacture of chenille shawls.—*Newton's Journal*, xxxvii. 148.

Carpets, Printed. Mr. Wood has taken a patent for weaving and printing carpets, using an ordinary Brussels carpet loom. After putting in the wire, or otherwise forming the loop, he throws in the usual linen shoot, on the face, to bind it; and then, for the back shoot, he throws in a thick soft weft. Or, to make a better edge and more elastic back, he employs the ordinary two linen shoots,—one on the face and the other in the back,—and then (or before throwing in the second linen shoot) he draws down only one-half of the lower portion of the linen warp (being one-quarter of the whole), and throws in the thick shoot, which is driven up by the batten or lay, so as to cover the second linen shoot, which is then inside the fabric: from the thick shoot being bound only by each alternate yarn of the warp, it will be more elastic than if bound more closely by using every yarn; whilst the second linen shoot, having half the warp over it, holds down the face or first shoot; and any inequality in the taking up of the lin warp, by one portion of it binding in a greater substance than the other, is remedied by drawing down the different portions in succession.

In printing Brussels and other pile carpets, the patentee first provides a table, long enough to receive the entire length or piece of the carpet to be printed; at each end of the table there is a frame of the same height or level, sufficiently long to receive the cylinder printing machine when off the fabric; and on the surface of the table the printing blanket is laid between two rails or guides, which are fixed at exactly the same distance apart as the carpet is wide, so as to keep it in one position, and to form the guides for the printing cylinders. The carpet is fastened to one end of the table, and is then laid on the top of the same, and drawn tight at the other end by a roller, which is furnished with a ratchet wheel and click. The printing cylinders are mounted in a movable frame, containing a corresponding number of colour cans and feeding rollers, to supply them with colour. This printing apparatus is passed over the table, and between the guide rails (the patterns on the cylinder being coloured, and bearing upon the carpet), to the frame at the other end of the table, and then back again; and this process is repeated until the fabric is sufficiently coloured. In order to insure each part of the pattern or printing surface coming again and again on the same place, toothed wheels are affixed on the axis of the printing cylinders, which geer into racks fixed on the sides of the table; so that, however frequently the printing apparatus passes over the fabric, every part of the pattern will fall on the same place. Instead of the printing apparatus being passed back again over same table, it may, by the application of movable frames at the end of the table, be moved sideways on to another table, and so successively.—*Newton's Journal*, xxxiv. 250.

CARTHAMUS, or safflower (carthamus tinctorius), (*Carthame*, Fr.; *Färber distel*, Germ.), the flower of which alone is used in dyeing, is an annual plant cultivated in Spain, Egypt, and the Levant. There are two varieties of it — one which has large leaves, and the other smaller ones. It is the last which is cultivated in Egypt, where it forms a considerable article of commerce.

Carthamus contains two coloring matters, one yellow and the other red. The first alone is soluble in water; its solution is always turbid: with re-agents it exhibits the characters usually remarked in yellow coloring matters. The acids render it lighter, the alkalis deepen it, giving it more of an orange hue: both produce a small dun precipitate, in consequence of which it becomes clearer. Alum forms a precipitate of a deep yellow, in small quantity. The solution of tin and the other metallic solutions cause precipitates which have nothing remarkable in them.

The yellow matter of carthamus is not employed; but in order to extract this portion, the carthamus is put into a bag, which is trodden under water, till no more color can be pressed out. The flowers, which were yellow, become reddish, and lose in this operation nearly one half of their weight. In this state they are used.

For extracting the red part of carthamus, and thereafter applying it to stuff, the property which alkalis possess of dissolving it is had recourse to, and it is afterwards precipitated by an acid.

The process of dyeing consists, therefore, in extracting the coloring matter by means of an alkali, and precipitating it on the stuff by means of an acid. It is this fecula which serves for making the rouge employed by ladies.

As to this rouge, the solution of carthamus is prepared with crystallized carbonate of soda, and it is precipitated by lemon juice. It has been remarked that lemons, beginning to spoil, were fitter for this operation than those which were less ripe, whose juice retained much mucilage. After squeezing out the lemon juice, it is left to settle for some days. The precipitate of carthamus is dried at a gentle heat upon plates of stone-ware; from which it is detached and very carefully ground with talc, which has been reduced to a very subtile powder, by means of the leaves of shave-grass (*presle*), and successively passed through sieves of increasing fineness. It is the fineness of the talc, and the greater or less proportion which it bears to the carthamus precipitate, which constitute the difference between the high and low priced rouges.

Carthamus is used for dyeing silk, poppy, *nacarat* (a bright orange-red), cherry, rose color, and flesh color. The process differs according to the intensity of the color, and the greater or less tendency to flame color that is wanted. But the carthamus bath whose application may be varied, is prepared as follows:

The carthamus, from which the yellow matter has been extracted, and whose lumps have been broken down, is put into a trough. It is repeatedly sprinkled with cendres gravelées (crude pearlashes), or soda (barilla) well powdered and sifted at the rate of 6 pounds for 120 lbs. of carthamus; but soda is preferred, mixing carefully as the alkali is introduced. This operation is called *amestier*. The *amestred* carthamus is put into a small trough with a grated bottom, first lining this trough with a closely woven cloth. When it is about half filled, it is placed over the large trough, and cold water is poured into the upper one, till the lower becomes full. The carthamus is then set over another trough, till the water comes from it almost colorless. A little more alkali is now mixed with it, and fresh water is passed through it. These operations are repeated till the carthamus be exhausted, when it turns yellow.

After distributing the silk in hanks upon the rods, lemon juice, brought in casks from Provence, is poured into the bath till it becomes of a fine cherry color; this is called turning the bath (*virer le bain*). It is well stirred, and the silk is immersed and turned round the skein-sticks in the bath, as long as it is perceived to take up the color. For *ponceau* (poppy color), it is withdrawn, the liquor is run out of it upon the peg, and it is turned through a new bath, where it is treated as in the first. After this it is dried and passed through fresh baths, continuing to wash and dry it between each operation, till it has acquired the depth of color that is desired. When it has reached the proper point, a brightening is given it by turning it round the sticks seven or eight times in a bath of hot water, to which about half a pint of lemon juice for each pailful of water has been added.

When silk is to be dyed *ponceau* or flame color, it must be previously boiled as for white; it must then receive a slight foundation of annotto, as explained in treating of this substance. The silk should not be alumed.

The *nacarats*, and the deep cherry colors, are given precisely like the *ponceaux*, only they receive no annotto ground; and baths may be employed which have served for the *ponceau*, so as to complete their exhaustion. Fresh baths are not made for the latter colors, unless there be no occasion for the poppy.

With regard to the lighter cherry-reds, rose color of all shades and flesh colors, they are made with the second and last runnings of the carthamus, which are weaker. The deepest shades are passed through first.

The lightest of all these shades, which is an extremely delicate flesh color, requires a little soap to be put into the bath. This soap lightens the color, and prevents it from taking too speedily, and becoming uneven. The silk is then washed, and a little brightening is given it, in a bath which has served for the deeper colors.

All these baths are employed the moment they are made, or as speedily as possible, because they lose much of their color upon keeping, by which they are even entirely destroyed at the end of a certain time. They are, moreover, used cold, to prevent the color from being injured. It must have been remarked in the experiments just described, that the caustic alkalis attack the extremely delicate color of carthamus, making it pass to yellow. This is the reason why crystals of soda are preferred to the other alkaline matters.

In order to diminish the expense of the carthamus, it is the practice in preparing the deeper shades to mingle with the first and the second bath about one fifth of the bath of archil.

Dobereiner regards the red coloring matter of carthamus as an acid, and the yellow as a base. His carthamic acid forms, with the alkalis, colorless salts, decomposed by the tartaric and acetic acids, which precipitate the acid of a bright rose-red. Heat has a remarkable influence upon carthamus, rendering its red color yellow and dull. Hence, the colder the water is by which it is extracted, the finer is the color. Light destroys the color very rapidly, and hitherto no means have been found of counteracting this effect. For this reason this brilliant color must be dried in the shade, its dye must be given in a shady place, and the silk stuffs dyed with it must be preserved as much as possible from the light. Age is nearly as injurious as light, especially upon the dye in a damp state. The color is very dear, because a thousand parts of carthamus contain only five of it.

In preparing the finest rouge, the yellow coloring matter being separated by washing with water, the red is then dissolved by the aid of alkali, and is thrown down on linen or cotton rags by saturating the solution with vegetable acid. The color is rinsed out of these rags, dissolved anew in alkalis, and once more precipitated by lemon juice. The best and freshest carthamus must be selected. It is put into linen bags, which are placed in a stream of water, and kneaded till the water runs off colorless. The bags are then put into water soured with a little vinegar, kneaded till the color is all expelled, and finally rinsed in running water. By this treatment the carthamus loses nearly half its weight. 6633 cwts. of safflower were imported into the United Kingdom in 1835, of which 2930 cwts. were retained for internal consumption.

CASE-HARDENING is the name of the process by which iron tools, keys, &c., have their surfaces converted into steel.

Steel when very hard is brittle, and iron alone is for many purposes, as for fine keys, far too soft. It is therefore an important desideratum to combine the hardness of a steely surface with the toughness of an iron body. These requisites are united by the process of case-hardening, which does not differ from the making of steel, except in the shorter duration of the process. Tools, utensils, or ornaments, intended to be polished, are first manufactured in iron and nearly finished, after which they are put into an iron box, together with vegetable or animal charcoal in powder, and cemented for a certain time. This treatment converts the external part into a coating of steel, which is usually very thin, because the time allowed for the cementation is much shorter than when the whole substance is intended to be converted. Immersion of the heated pieces into water hardens the surface, which is afterwards polished by the usual methods. Moxon, in his *Mechanic Exercises*, p. 56, gives the following receipt for case-hardening:—"Cow's horn or hoof is to be baked or thoroughly dried and pulverized. To this add an equal quantity of bay salt; mix them with stale chamber-ley or white wine vinegar: cover the iron with this mixture, and bed it with the same in loam, or enclose it in an iron box; lay it on the hearth of the forge to dry and harden: then put it into the fire, and blow till the lump have a blood-red heat, and no higher, lest the mixture be burnt too much. Take the iron out, and immerse it in water to harden." I consider the vinegar to be quite superfluous.

I shall now describe the recent application of prussiate (ferrocyanate) of potash to this purpose. The piece of iron, after being polished, is to be made brightly red-hot, and then rubbed or sprinkled over with the above salt in fine powder, upon the part intended to be hardened. The prussiate being decomposed, and apparently dissipated, the iron is to be quenched in cold water. If the process has been well managed, the surface of the metal will have become so hard as to resist the file. Others propose to smear over the surface of the iron with loam made into a thin paste with a strong solution of the prussiate, to dry it slowly, then expose the whole to a nearly white heat, and finally plunge the iron into cold water, when the heat has fallen to dull redness. See STEEL.

CASHMERE or CACHEMERE, a peculiar textile fabric first imported from the kingdom of Cashmere, and now well imitated in France and Great Britain. The material of the Cashmere shawls is the downy wool found about the roots of the hair of the Thibet goat. The year 1819 is remarkable in the history of French husbandry for the acquisition of this breed of goats, imported from the East under the auspices of their government, by the indefatigable courage and zeal of M. Jaubert, who encountered every fatigue and danger to enrich his country with these valuable animals, aided by the patriotism of M. Ternaux, who first planned this importation, and furnished funds for executing it at his own expense and responsibility. He placed a portion of the flock brought by M. Jaubert, at his villa of Saint Ouen, near Paris, where the climate seemed to be very favorable to them, since for several successive years after their introduction M. Ternaux was enabled to sell a great number of both male and female goats. The quantity of fine fleece or down afforded by each animal annually, is from a pound and a half to two pounds.

The wool imported into Europe comes by the way of Casan, the capital of a government of the Russian empire upon the eastern bank of the Wolga; it has naturally a grayish color, but is easily bleached. Its price a few years back at Paris was 17 francs per kilogramme; that is, about 6 shillings the pound avoirdupois. The waste in picking, carding, and spinning, amounts to about one third of its weight.

The mills for spinning Cachemere wool have multiplied very much of late years in France, as appears from the premiums distributed at the exposition of 1834, and the prices of the yarn have fallen from 25 to 30 per cent. notwithstanding their improved fineness and quality. There is a fabric made with a mixture of Cachemere down and spun silk, which is becoming very general. One of the manufacturers, M. Hindenlang, exhibited samples of Cachemere cloth woven with yarn so fine as No. 130 for warp, and No. 228 for weft.

Messrs. Pollino, brothers, of Paris, produced an assortment of Cachemere pieces from 22 to 100 francs the yard, dyed of every fancy shade. Their establishment at Ferté-Bernard occupies 700 operatives, with an hydraulic wheel of 60 horse power.

The oriental Cashmere shawls are woven by processes extremely slow and consequently costly; whence their prices are very high. They are still sold in Paris at from 4,000 to 10,000 francs a piece; and from 100 to 400 pounds sterling in London. It became necessary, therefore, either to rest satisfied with work which should have merely a surface appearance, or contrive economical methods of weaving, to produce the real Cachemere style with much less labor. By the aid of the draw-loom, and still better of the Jacquard loom, M. Ternaux first succeeded in weaving Cachemere shawls perfectly similar to the oriental in external aspect, which became fashionable under the name of French Cachemere. But to construct shawls altogether identical on both sides with the eastern, was a more difficult task, which was accomplished only at a later period by M. Bauson of Paris.

In both modes of manufacture, the piece is mounted by reeding-in the warp for the different leaves of the heddles, as is commonly practised for warps in the Jacquard looms. The weaving of imitation shawls is executed, as usual, by as many shuttles as there are colors in the design, and which are thrown across the warp in the order established by the *reeder*. The greater number of these weft yarns being introduced only at intervals into the web, when the composition of the pattern requires it, they remain floating loose at the back of the piece, and are cut afterwards, without affecting in the least the quality of the texture; but there is a considerable waste of stuff in the weaving, which is worked up into carpets.

The weaving of the imitation of real Cachemere shawls is different from the above. The yarns intended to form the weft are not only equal in number to that of the colors of the pattern to be imitated, but besides this, as many little shuttles or pirns (like those used by embroiderers) are filled with these yarns, as there are to be colors repeated in the breadth of the piece; which renders their number considerable when the pattern is somewhat complicated and loaded with colors. Each of these small bobbins or shuttles passes through only that portion of the flower in which the color of its yarn is to appear, and stops at the one side and the other of the cloth exactly at its limit; it then returns upon itself after having crossed the thread of the adjoining shuttle. From this reciprocal intertexture of all the yarns of the shuttles, it results, that although the weft is composed of a great many different threads, they no less constitute a continuous line in the whole breadth of the web, upon which the lay or batten acts in the ordinary way We see, therefore, that the whole art of manufacturing this Cachemere cloth consists in avoiding the confusion of the shuttles, and in not striking up the lay till all have fulfilled their function. The labor does not exceed the strength of a woman, even though she has to direct the loom and work the treddles. Seated on her bench at the end opposite to the middle of the beam, she has for aids in weaving shawls from 45 to 52 inches wide, two girl apprentices, whom she directs and instructs in their tasks. About four hundred days of work are required for a Cachemere shawl of that breadth. For the construction of the loom, see JACQUARD.

In the oriental process, all the figures in relief are made simply with a slender pirn without the shuttle used in European weaving. By the Indians the flower and its ground are made with the pirn, by means of an intertwisting, which renders them in some measure independent of the warp. In the Lyons imitation of this style, the leaves of the heddles lift the yarns of the warp, the needles embroider as in lappet weaving, and the flower is united to the warp by the weft thrown across the piece. Thus a great deal of labor is saved, the eye is pleased with an illusion of the loom, and the shawls cost little more than those made by the common fly shuttle.

Considered in reference to their materials, the French shawls present three distinct classes, which characterize the three fabrics of Paris, Lyons, and Nimes.

Paris manufactures the French Cachemere, properly so called, of which both the warp and the weft are the yarn of pure Cachemere down. This web represents with fidelity the figures and the shades of color of the Indian shawl, which it copies; the deception would be complete if the reverse of the piece did not show the cut ends. The Hindoo shawl, also woven at Paris, has its warp in spun silk, which reduces its price without impairing its beauty much.

Lyons, however, has made the greatest progress in the manufacture of shawls. It excels particularly in the texture of its Thibet shawls, the weft of which is yarn spun with a mixture of wool and spun silk.

Nimes is remarkable for the low price of its shawls, in which spun silk, Thibet down, and cotton, are all worked up together.

The value of shawls exported from France in the following years was—

	1831.	1832.	1833.
	Francs.	Francs.	Francs.
Woollen - - - - - -	1,863,147	2,070,926	4,319,601
Cachemere down - -	433,410	655,200	609,900
Spun silk - - - - - -	401,856	351,152	408,824

It appears that M. J. Girard at Sèvres, near Paris, has succeeded best in producing Cachemere shawls equal in stuff and style of work to the oriental, and at a lower price. They have this advantage over the Indian shawls, that they are woven without seams, in a single piece, and exhibit all the variety and the raised effect of the eastern colors. Women and children alone are employed in his factory.

CASK (*Tonneau*, Fr.; *Fass*, Germ.), manufacture of by mechanical power. Mr. Samuel Brown obtained a patent in November, 1825, for certain improvements in machinery for making casks, which seems to be ingenious and worthy of record. His mechanism consists in the first place of a circular saw attached to a bench, with a sliding rest, upon which rest each piece of wood intended to form a stave of a cask is fixed; and the rest being then slidden forward in a curved direction, by the assistance of an adjustable guide, brings the piece of wood against the edge of the rotatory saw, and causes it to be cut into the curved shape required for the edge of the stave. The second feature is an apparatus with cutters attached to a standard, and traversing round with their carrier upon a centre, by means of which the upper and lower edges of the cask are cut round and grooved, called chining, for the purpose of receiving the heads. Thirdly, an apparatus not very dissimilar to the last, by which the straight pieces of wood designed for the heads of the cask are held together, and cut to the circular figure required, and also the bevelled edges produced. And fourthly, a machine in which the cask is made to revolve upon an axis, and a cutting tool to traverse for the purpose of shaving the external part of the cask, and bringing it to a smooth surface.

The pieces of wood intended to form the staves of the cask, having been cut to their required length and breadth, are placed upon the slide-rest of the first mentioned machine, and confined by cramps; and the guide, which is a flexible bar, having been previously bent to the intended curve of the stave and fixed in that form, the rest is then slidden forward upon the bench by the hand of the workman, which as it advances (moving in a curved direction) brings the piece of wood against the edge of the revolving circular saw, by which it is cut to the curved shape desired.

The guide is a long bar held by a series of movable blocks fitted to the bench by screws, and is bent to any desired curve by shifting the screws: the edge of the slide-rests which holds the piece of wood about to be cut, runs against the long guide bar, and of consequence is conducted in a corresponding curved course. The circular saw receives a rapid rotatory motion by means of a band or rigger from any first mover; and the piece of wood may be shifted laterally by means of racks and pinions on the side-rest, by the workman turning a handle, which is occasionally necessary in order to bring the piece of wood up to, or away from, the saw.

The necessary number of staves being provided, they are then set round within a confining hoop at bottom, and brought into the form of a cask in the usual way, and braced by temporary hoops. The barrel part of the cask being thus prepared, in order to effect the chining, it is placed in a frame upon a platform, which is raised up by a treddle lever, that the end of the barrel may meet the cutters in a sort of lathe above: the cutters are then made to traverse round within the head of the barrel, and, as they proceed, occasionally to expand, by which means the bevels and grooves are cut on the upper edge of the barrel, which is called chining. The barrel being now reversed, the same apparatus is brought to act against the other end, which becomes chined in like manner.

The pieces of wood intended to form the heads of the cask are now to be cut straight by a circular saw in a machine, similar to the first described; but in the present instance the slide-rest is to move forward in a straight course. After their straight edges are thus produced, they are to be placed side by side, and confined, when a scribing cutter is made to traverse round, and cut the pieces collectively into the circular form desired for heading the cask.

The cask having now been made up, and headed by hand as usual, it is placed between centres, or upon an axle in a machine, and turned round by a rigger or band with a shaving cutter, sliding along a bar above it, which cutter, being made to advance and recede as it slides along, shaves the outer part of the cask to a smooth surface.

CASSAVA. *Cassava bread, conaque, &c.*, are different names given to the starch of the root of the Manioc (*Jatropha Manihot*, Linn.), prepared in the following manner in the West Indies, the tropical regions of America, and upon the African coast. The tree belongs to the natural family of the *euphorbiaceæ*.

The roots are washed, and reduced to a pulp by means of a rasp or grater. The pulp is put into coarse strong canvass bags, and thus submitted to the action of a powerful press, by which it parts with most of its noxious juice (used by the Indians for poisoning the barbs of their arrows.) As the active principle of this juice is volatile, it is easily dissipated by baking the squeezed cakes of pulp upon a plate of hot iron. Fifty pounds of the fresh juice, when distilled, afford, at first, three ounces of a poisonous water, possessing an intolerably offensive smell; of which, 35 drops being administered to a slave convicted of the crime of poisoning, caused his death in the course of six minutes, amid horrible convulsions.*

The pulp dried in the manner above described concretes into lumps, which become hard and friable as they cool. They are then broken into pieces, and laid out in the sun to dry. In this state they afford a wholesome nutriment, and are habitually used as such by the negroes, as also by many white people. These cakes constitute the only provisions laid in by the natives, in their voyages upon the Amazons. Boiled in water with a little beef or mutton they form a kind of soup similar to that of rice.

The cassava cakes sent to Europe (which I have eaten with pleasure) are composed almost entirely of starch, along with a few fibres of the ligneous matter. It may be purified by diffusion through warm water, passing the milky mixture through a linen cloth, evaporating the strained liquid over the fire, with constant agitation. The starch dissolved by the heat, thickens as the water evaporates, but on being stirred, it becomes granulated, and must be finally dried in a proper stove. Its specific gravity is 1·530 — that of the other species of starch.

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* Memoir of Dr. Fermin, communicated to the Academy of Berlin concerning experiments made at Cayenne upon the juice of the Manioc.

The product obtained by this treatment is known in commerce under the name of *tapioca ;* and being starch very nearly pure, is often prescribed by physicians as an aliment of easy digestion. A tolerably good imitation of it is made by heating, stirring, and drying potato starch in a similar way.

The expressed juice of the root of manioc contains in suspension a very fine fecula, which it deposites slowly upon the bottom of the vessels. When freed by decantation from the supernatant liquor, washed several times and dried, it forms a beautiful starch, which creaks on pressure with the fingers. It is called *cipipa,* in French Guyana; it is employed for many delicate articles of cookery, especially pastry, as also for hair powder, starching linen, &c.

Cassava flour, as imported, may be distinguished from arrow-root and other kinds of starch, by the appearance of its particles viewed in a microscope. They are spherical, all about 1-1000th of an inch in diameter, and associated in groups ; those of potato starch are irregular ellipsoids, varying in size from 1-300th to 1-3000th of an inch; those of arrow-root have the same shape nearly, but vary in size from 1-500th to 1-800th of an inch; those of wheat are separate spheres 1-1000th of an inch.

CASSIS, the black currant (*ribes nigra,* Linn.), which was formerly celebrated for its medicinal properties with very little reason.

The only technical use to which it is now applied is in preparing the agreeable *liqueur* called *ratafia,* by the following French recipe:—Stone, and crush three pounds of black currants, adding to the magma one drachm of cloves, two of cinnamon, four quarts of spirit of wine, at 98° Baumé (see Areomètre of Baumé), and 2½ pounds of sugar. Put the mixture into a bottle which is to be well corked ; let it digest for a fortnight, shaking the bottle once daily during the first eight days; then strain through a linen cloth, and finally pass through filtering paper.

CASSIUS, *purple powder of.* A preparation used in the arts as a colour, chiefly for stained glass and porcelain. It is also employed in medicine by some French physicians, and has been prepared by the following prescription:—10 parts of acid chloride of gold are dissolved in 2000 parts of water. In another vessel, 10 parts of pure tin are dissolved in 10 parts of nitric acid mixed with 20 parts of hydrochloric, and this solution is diluted with 1000 parts of distilled water. The solution of tin is added by degrees to that of the acid chloride of gold, as long as any precipitate results which is allowed to subside; it is then washed, filtered, and then dried at a very gentle heat. The tin salt above used contains both the protoxide and binoxide in certain proportions. The double compound of chloride of tin with sal ammoniac, called the pink salt of tin, is the preferable form; as it is not altered by the atmosphere, is of definite composition, and when boiled with metallic tin it takes up just so much as will form the protochloride; 100 parts of pink salt require for this purpose 10·7 parts of metallic tin.

1·34 gr. of gold are to be dissolved in *aqua regia,* without excess of the solvent, and this solution is to be diluted with 480 gr. of water. Then 10 gr. of the pink salt mixed with 1·07 gr. of tin filings, and 40 gr. of water, are to be exposed to a boiling heat till the metal is dissolved. 140 gr. of water are now to be poured upon that compound, and the resulting solution is to be gradually added to the gold liquor (slightly warmed) till no more precipitate forms. This when washed and dried is of a brown colour, and weighs 4·92 grs. The above method of preparing the solution of the sesquioxide of tin seems to be the best hitherto prescribed.

CASTING OF METALS. (See Founding.) *Casts from elastic moulds.*—Being much engaged in taking casts from anatomical preparations, Mr. Douglas Fox, Surgeon, Derby, found great difficulty, principally with hard bodies, which, when undercut, or having considerable overlaps, did not admit of the removal of moulds of the ordinary kind, except with injury. These difficulties suggested to him the use of elastic moulds, which, giving way as they were withdrawn from complicated parts, would return to their proper shape; and he ultimately succeeded in making such moulds of glue which not only relieved him from all his difficulties, but were attended with great advantages, in consequence of the small number of pieces into which it was necessary to divide the mould.

The body to be moulded, previously oiled, must be secured one inch above the surface of a board, and then surrounded by a wall of clay, about an inch distant from its sides. The clay must also extend rather higher than the contained body: into this, warm melted glue, as thick as possible so that it will run, is to be poured, so as to completely cover the body to be moulded; the glue is to remain till cold, when it will have set into an elastic mass, just such as is required.

Having removed the clay, the glue is to be cut into as many pieces as may be necessary for its removal, either by a sharp-pointed knife, or by having placed threads in the requisite situations of the body to be moulded, which may be drawn away when the glue is set, so as to cut it out in any direction.

The portions of the glue mould having been removed from the original, are to be placed together and bound round by tape.

In some instances it is well to run small wooden pegs through the portions of glue, so as to keep them exactly in their proper positions. If the mould be of considerable size, it is better to let it be bound with moderate tightness upon a board to prevent it bending whilst in use; having done as above described, the plaster of Paris, as in common casting, is to be poured into the mould, and left to set.

In many instances wax may also be cast in glue, if it is not poured in whilst too hot; as the wax cools so rapidly when applied to the cold glue, that the sharpness of the impression is not injured.

Glue has been described as succeding well where the elastic mould is alone applicable; but many modifications are admissible. When the moulds are not used soon after being made, treacle should be previously mixed with the glue (as employed by printers) to prevent it becoming hard.

The description thus given is with reference to moulding those bodies which cannot be so done by any other than an elastic mould; but glue moulds will be found greatly to facilitate casting in many departments, as a mould may be frequently taken by this method in two or three pieces, which would, on any other principle, require many.

CAST-IRON SCOURING. Cast-iron surfaces are said to be easily scoured by adding a little of any kind of organic matter, such as glycerine, stearine, napthaline, creosote to dilute sulphuric acid; zinc and brass yield to the same method, with great economy of labour, time and material,

CASTOR. (Eng. and Fr.; *Biber*, Germ.) The castor is an amphibious quadruped, inhabiting North America; also found in small numbers in the islands of the Rhone. In the arts, the skin of this animal is employed either as a fur or as affording the silky hair called beaver, with which the best hats are covered. Beaver skins, which form a very considerable article of trade, are divided into 3 sorts: 1. The fresh beaver skins from castors, killed in winter before shedding their hair; these are most in request among the furriers, as being the most beautiful. 2. The dry or lean beavers are the skins of the animals killed during the moulting season; they are not much esteemed, as the skin is rather bare. 3. The fat castors: these are the skins of the first sort, which have been worn for some time upon the persons of the savages, and have got imbued with their sweat. The last are principally used in the hat manufacture. In France, the marine otter has been for many years substituted in the place of the castor or beaver.

CASTOR or CASTOREUM. This name is given to a secretion of the castors, contained in pear-shaped cellular organic sacs, placed near the genital organs of both the male and female animals. It is a substance analogous to civet and musk, of a consistence similar to thick honey. It has a bitter acrid taste; a powerful, penetrating, fetid, and very volatile smell; but, when dried, it becomes inodorous. Several chemists, and in particular Bouillon Lagrange, Laugier, and Hildebrandt, have examined castor, and found it to be composed of a resin, a fatty substance, a volatile oil, an extractive matter, benzoic acid, and some salts.

The mode of preparing it is very simple. The sacs are cut off from the castors when they are killed, and are dried to prevent the skin being affected by the weather. In this state, the interior substance is solid, of a dark color, and a faint smell; it softens with heat, and becomes brittle by cold. Its fracture betrays fragments of membranes, indicating its organic structure. When chewed, it adheres to the teeth somewhat like wax; it has a bitter, slightly acrid, and nauseous taste.

The castor bags, as imported, are often joined in pairs by a kind of ligature. Some times the substance which constitutes their value is sophisticated; a portion of the castoreum being extracted, and replaced by lead, clay, gums, or some other foreign matters. This fraud may be easily detected, even when it exists in a small degree, by the absence of the membranous partitions in the interior of the bags, as well as by the altered smell and taste.

The use of castoreum in medicine is considerable, especially in nervous and spasmodic diseases, and it is often advantageously combined with opium.

CASTORINE. A chemical principle lately discovered to the amount of a few parts per cent. in Castoreum.

CASTOR OIL. The expressed oil of the seeds of the *Palma Christi*, or *Ricinus communis*, a native tree of the West Indies and South America; but which has been cultivated in France, Italy, and Spain. Bussy and Lecanu discovered in it 3 species of fatty matters, obtained partly by saponification, and partly by dry distillation—the margaritic, ricinic, and elaiodic acids. None of these has been separately applied to any use in the arts.

The quantity of castor oil imported in 1835 into the United Kingdom was 1,109,307 lbs.; retained for home consumption, 670,205 lbs. See Oils.

CATECHU, absurdly called Terra Japonica, is an extract made from the wood of the tree *mimosa catechu*, which grows in Bombay, Bengal, and other parts of India. It is prepared by boiling the chips of the interior of the trunk in water, evaporating the solution to the consistence of sirup over the fire, and then exposing it in the sun to harden. It occurs in flat rough cakes, and under two forms. The first, or the Bombay, is of uniform texture, of a dark red color, and of specific gravity 1·39. The second is more friable and less solid. It has a chocolate color, and is marked inside with red streaks. Its specific gravity is 1·28.

According to Sir H. Davy, these two species are composed as follows:—

	Bombay.	Bengal.
Tannin - - - - - - - -	54·5	48·5
Extractive - - - - - -	34·0	36·5
Mucilage - - - - - -	6·5	8
Insoluble matters, sand and lime - -	5	7
	100·0	100·0

Areka nuts are also found to yield catechu; for which purpose they are cut into pieces watered in an earthen pot with solution of nitre, and have a little of the bark of a species of mimosa added to them. The liquor is then boiled with the nuts, and affords an inspissated decoction.

Good catechu is a brittle, compact solid, of a dull fracture. It has no smell, but a very astringent taste. Water dissolves the whole of it, except the earthy matter, which is probably added during its preparation. Alcohol dissolves its tannin and extractive. The latter may be oxydized, and thus rendered insoluble in alcohol, by dissolving the catechu in water, exposing it for some time to a boiling heat, and evaporating to dryness.

The tannin of catechu differs from that of galls, in being soluble in alcohol, and more soluble in water. It precipitates iron of an olive color, and gelatin in a mass which gradually becomes brown.

It has been long employed in India for tanning skins, where it is said to effect this object in five days. I have seen a piece of sole leather completely tanned by it in this country in ten days, the ox-hide having been made into a bag, with the hair outside, and kept filled with the solution of catechu. In India it has also been used to give a brown dye to cotton goods, and of late years it has been extensively introduced into the calico print works of Europe. The salts of copper with sal ammoniac cause it to give a bronze color, which is very fast; the proto-muriate of tin, a brownish yellow; the per-chloride of tin, with the addition of nitrate of copper, a deep bronze hue; acetate of alumina alone, a reddish brown, and, with nitrate of copper, a reddish olive gray; nitrate of iron, a dark brown gray. For dyeing a golden coffee brown, it has entirely superseded madder; one pound of it being equivalent to six pounds of this root.

A solution of one part of catechu in ten parts of water, which is reddish brown, exhibits the following results: with—

Acids - - - -	A brightened shade.
Alkalis - - - -	A darkened shade.
Proto-sulphate of iron -	Olive brown precipitate.
Per-sulphate of iron -	Olive green do.
Sulphate of copper - -	Yellowish brown.
Alum - - - -	A brightening of the liquor.
Per-nitrate of iron - -	Olive green precipitate.
Nitrate of copper - -	Yellowish brown do.
Nitrate of lead - -	Salmon do.
Proto-nitrate of mercury -	Milk-coffee do.
Muriate of alumina -	Brown-yellow.
Muriate of tin - -	Do. do.
Per-chloride of tin - -	Do. darker.
Corrosive sublimate -	Light chocolate do.
Acetate of alumina - -	Brightening of the liquor.
Acetate of copper - -	Copious brown precipitate
Acetate of lead - -	Salmon colored do.
Bichromate of potash -	Copious brown do.

Pure tannin may be obtained from catechu, by treating it with sulphuric acid and carbonate of lead; but this process has no manufacturing application.

CATGUT (*Corde à boyau*, Fr.; *Darmsaite*, Germ.), the name absurdly enough given to cords made of the twisted intestines of the sheep. The guts being taken while warm out of the body of the animal, are to be cleared of feculent matter, freed from any adhering fat, and washed in a tub of water. The small ends of all the intestines are next to be tied together, and laid on the edge of the tub, while the body of them is left to steep in some water, frequently changed, during two days, in order to loosen the peritoneal and mucous membranes. The bundle of intestines is then laid upon a sloping table which overhangs the tub, and their surface is scraped with the back of a knife, to try if the external membrane will come away freely in breadths of about half the circumference. This substance is called by the French manufacturers *filandre*, and the process *filer*. If we attempt to remove it by beginning at the large end of the intestine, we shall not succeed. This *filandre* is employed as thread to sew intestines, and to make the cords of rackets and battledoors. The flayed guts are put again into fresh water, and, after steeping a night, are taken out and scraped clean next day, on the wooden bench with the rounded back of a knife. This is called *curing the gut*. The large ends are now cut off, and sold to the pork-butchers. The intestines are again steeped for a night in fresh water, and the following day in an alkaline lixivium made by adding 4 ounces of potash, and as much pearl-ash, to a pail of water containing about 3 or 4 imperial gallons. This ley is poured in successive quantities upon the intestines, and poured off again, after 2 or 3 hours, till they be purified. They are now drawn several times through an open brass thimble, and pressed against it with the nail, in order to smooth and equalize their surface. They are lastly sorted, according to their sizes, to suit different purposes.

Whip-cord is made from the above intestines, which are sewed together endwise by the *filandre*, each junction being cut aslant, so as to make it strong and smooth. The cord is put into the frame, and each end is twisted separately; for whip-cord is seldom made out of two guts twisted together. When twisted, it is to be sulphured (see SULPHURING) once or twice. It may also be dyed black with common ink, pink with red ink, which the sulphurous acid changes to pink, and green with a green dye which the color dealers sell for the purpose. The guts take the dyes readily. After being well smoothed, the cord is to be dried, and coiled up for sale.

Hatters' cords for bowstrings.—The longest and largest intestines of sheep, after being properly treated with the potash, are to be twisted 4, 6, 8, 10, or 12 together, according to the intended size of the cord, which is usually made from 15 to 25 feet long. This cord must be free from seams and knots. When half dry, it must be exposed twice to the fumes of burning sulphur; and, after each operation, it is to be well stretched and smoothed: it should be finally dried in a state of tension.

Clockmaker's cord.—This cord should be extremely thin, and be therefore made from very small intestines, or from intestines slit up in their length by a knife fitted for the purpose; being a kind of lancet surmounted with a ball of lead or wood. The wet gut is strained over the ball which guides the knife, and the two sections fall down into a vessel placed beneath. Each hand pulls a section. Clockmakers also make use of stronger cords made of 2 or more guts twisted together.

Fiddle and harp strings. — These require the greatest care and dexterity on the part of the workmen. The treble strings are peculiarly difficult to make, and are best made at Naples, probably because their sheep, from their small size and leanness, afford the best raw material.

The first scraping of the guts intended for fiddle-strings must be very carefully performed; and the alkaline leys, being clarified with a little alum, are added, in a progressively stronger state from day to day, during 4 or 5 days, till the guts be well bleached and swollen. They must then be passed through the thimble, and again cleansed with the lixivium; after which they are washed, spun, or twisted and sulphured during two hours. They are finally polished by friction, and dried. Sometimes they are sulphured twice or thrice before being dried, and are polished between norse-hair cords.

It has been long a subject of complaint, as well as a serious inconvenience to musicians, that catgut strings cannot be made in England of the same goodness and strength as those imported from Italy. These are made of the peritoneal covering of the intestines of the sheep; and, in this country, they are manufactured at Whitechapel, and probably elsewhere in considerable quantity; the consumption of them for harps, as well as for the instruments of the violin family, being very great. Their chief fault is weakness; whence it is difficult to bring the smaller ones, required for the higher notes, to concert pitch; maintaining at the same time, in their form and construction, that tenuity or smallness of diameter, which is required to produce a brilliant and clear tone.

The inconvenience arising from their breaking when in use, and the expense in the case of harps, where so many are required, are such as to render it highly desirable to improve a manufacture which, to many individuals may, however, appear sufficiently contemptible.

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It is well known to physiologists, that the membranes of lean animals are far more tough than of those animals which are fat or in high condition; and there is no reason to doubt that the superiority of the Italian strings arises from the state of the sheep in that country. In London, where no lean animals are slaughtered, and where, indeed, an extravagant and useless degree of fattening, at least for the purpose of food, is given to sheep in particular, it is easy to comprehend why their membranes can never afford a material of the requisite tenacity. It is less easy to suggest an adequate remedy; but a knowledge of the general principle, should this notice meet the eyes of those interested in the subject, may at least serve the purpose of diminishing the evil and improving the manufacture, by inducing them to choose in the market the offal of such carcasses as appear least overburdened with fat. It is probable that such a manufacture might be advantageously established in those parts of the country where the fashion has not, as in London, led to the use of meat so much overfed; and it is equally likely, that in the choice of sheep for this purpose, advantage would arise from using the Welch, the Highland, or the Southdown breeds, in preference to those which, like the Lincoln, are prone to excessive accumulations of fat. It is equally probable, that sheep dying of some of the diseases accompanied by emaciation, would be peculiarly adapted to this purpose.

That these suggestions are not merely speculative is proved by comparing the strength of the membranes in question, or that of the other membranous parts, in the unfattened Highland sheep, with that of those found in the London markets.

CATHARTINE. The name proposed by MM. Feneulle and Lassaigne for a chemical principle, which they suppose to be the active constituent of senna.

CAUSTIC. Any chemical substance corrosive of the skin and flesh; as potash, called common caustic, and nitrate of silver, called lunar caustic, by surgeons.

CAVIAR. The salted roe of certain species of fish, especially the sturgeon. This product forms a considerable article of trade, being exported annually from the town of Astrachan alone, upon the shores of the Caspian sea, to the amount of several hundred tons. The Italians first introduced it into Eastern Europe from Constantinople, under the name of *caviale*. Russia has now monopolized this branch of commerce. It is prepared in the following manner:—

The female sturgeon is gutted; the roe is separated from the other parts, and cleaned by passing it through a very fine searce, by rubbing it into a pulp between the hands; this is afterwards thrown into tubs, with the addition of a considerable quantity of salt; the whole is then well stirred, and set aside in a warm apartment. There is another sort of caviar, the compressed, in which the roe, after having been cured in strong brine, is dried in the sun, then put into a cask, and subjected to strong pressure.

CAWK. The English miner's name for sulphate of baryta, or heavy spar.

CEDRA (*Cedrat*, Fr.) is the fruit of a species of orange, citron, or lemon, a tree which bears the same name. Its peel is very thick, and covered with an epidermis which encloses a very fragrant and highly prized essential oil. The preserves flavored with it are very agreeable. The citrons are cut into quarters for the dry comfits, but are put whole into the liquid ones. The liquorist-perfumer makes with the peel of the *cedra* an excellent *liqueur;* for which purpose, he plucks them before they are quite ripe; grates down the peel into a little brandy, or cuts them into slices, and infuses these in the spirits. This infusion is distilled for making perfume; but the flavor is better when the infusion itself is used. See ESSENCES, LIQUORIST, PERFUMERY.

CELESTINE. Native sulphate of strontia, found abundantly near Bristol, in the red marl formation. It is decomposed, by ignition with charcoal, into sulphuret of strontia, which is converted into nitrate by saturation with nitric acid, evaporation, and crystallization. This nitrate is employed for the production of the red light in theatrical fire-works.

CEMENTATION. A chemical process, which consists in imbedding a solid body in a pulverulent matter, and exposing both to ignition in an earthen or metallic case. In this way, iron is cemented with charcoal to form steel, and bottle glass with gypsum powder, or sand, to form Reaumur's porcelain.

CEMENTS. (*Ciments*, Fr.; *Cämente*, *Kitte*, Germ.) Substances capable of taking the liquid form, and of being in that state applied between the surfaces of two bodies, so as to unite them by solidifying. They may be divided into two classes, those which are applied through the agency of a liquid menstruum, such as water, alcohol, or oil, and those which are applied by fusion with heat.

The *diamond* cement for uniting broken pieces of china, glass, &c., which is sold as a secret at an absurdly dear price, is composed of isinglass soaked in water till it becomes soft, and then dissolved in proof spirit, to which a little gum resin, ammoniac, or galbanum, and resin mastic are added, each previously dissolved in a minimum of alcohol. When to be applied, it must be gently heated to liquefy it; and it should be kept for use in a well-corked vial. A glass stopper would be apt to fix so as not to be remove able. This is the cement employed by the Armenian jewellers in Turkey for glueing the ornamental stones to trinkets of various kinds. When well made it resists moisture.

Shellac dissolved in alcohol, or in a solution of borax, forms a pretty good cement. White of egg alone, or mixed with finely sifted quicklime, will answer for uniting objects which are not exposed to moisture. The latter combination is very strong, and is much employed for joining pieces of spar and marble ornaments. A similar composition is used by copper-smiths to secure the edges and rivets of boilers; only bullock's blood is the albuminous matter used instead of white of egg. Another cement in which an analogous substance, the curd or caseum of milk is employed, is made by boiling slices of skim-milk cheeses into a gluey consistence in a great quantity of water, and then incorporating it with quicklime on a slab with a muller, or in a marble mortar. When this compound is applied warm to broken edges of stoneware, it unites them very firmly after it is cold.

A cement which gradually indurates to a stony consistence may be made by mixing 20 parts of clean river sand, two of litharge, and one of quicklime, into a thin putty with linseed oil. The quicklime may be replaced with litharge. When this cement is applied to mend broken pieces of stone, as steps of stairs, it acquires after some time a stony hardness. A similar composition has been applied to coat over brick walls, under the name of mastic.

The iron-rust cement is made of from 50 to 100 parts of iron borings, pounded and sifted, mixed with one part of sal-ammoniac, and when it is to be applied moistened with as much water as will give it a pasty consistency. Formerly flowers of sulphur were used, and much more sal-ammoniac in making this cement, but with decided disadvantage, as the union is effected by the oxydizement, consequent expansion and solidification of the iron powder, and any heterogeneous matter obstructs the effect. The best proportion of sal-ammoniac is, I believe, one per cent. of the iron borings. Another composition of the same kind is made by mixing 4 parts of fine borings or filings of iron, 2 parts of potter's clay, and 1 part of pounded potsherds, and making them into a paste with salt and water. When this cement is allowed to concrete slowly on iron joints, it becomes very hard.

For making architectural ornaments in relief, a moulding composition is formed of chalk, glue, and paper paste. Even statues have been made with it, the paper aiding the cohesion of the mass.

Mastics of a resinous or bituminous nature which must be softened or fused by heat are the following:—

Mr. S. Varley's consists of sixteen parts of whiting sifted and thoroughly dried by a red heat, adding when cold a melted mixture of 16 parts of black rosin and 1 of bees'-wax, and stirring well during the cooling.

Mr. Singer's electrical and chemical apparatus cement consists of 5 lbs. of rosin, 1 of bees'-wax, 1 of red ochre, and two table-spoonsful of Paris plaster, all melted together. A cheaper one for cementing voltaic plates into wooden troughs is made with 6 pounds of rosin, 1 pound of red ochre, ½ of a pound of plaster of Paris, and ¼ of a pound of linseed oil. The ochre and the plaster of Paris should be calcined beforehand, and added to the other ingredients in their melted state. The thinner the stratum of cement that is interposed, the stronger, generally speaking, is the junction.

Boiled linseed oil and red lead mixed together into a putty are often used by coppersmiths and engineers, to secure joints. The washers of leather or cloth are smeared with this mixture in a pasty state.

The resin mastic alone is sometimes used by jewellers to cement by heat cameos of white enamel or colored glass to a real stone, as a ground to produce the appearance of an onyx. Mastic is likewise used to cement false backs or doublets to stones, to alter their hue.

Melted brimstone, either alone, or mixed with rosin and brick dust, forms a tolerably good and very cheap cement.

Plumber's cement consists of black rosin one part, brick-dust two parts, well incorporated by a melting heat.

The cement of dihl for coating the fronts of buildings consists of linseed oil, rendered dry by boiling with litharge, and mixed with porcelain clay in fine powder, to give it the consistence of stiff mortar. Pipe-clay would answer equally well if well dried, and any color might be given with ground bricks, or pottery. A little oil of turpentine to thin this cement aids its cohesion upon stone, brick, or wood. It has been applied to sheets of wire cloth, and in this state laid upon terraces, in order to make them water tight; but it is little less expensive than lead.

The bituminous or black cement for bottle-corks consists of pitch hardened by the addition of rosin and brick-dust.

In certain localities where a limestone impregnated with bitumen occurs, it is dried,

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ground, sifted, and then mixed with about its own weight of melted pitch, either mineral, vegetable, or that of coal tar. When this mixture is getting semifluid, it may be moulded into large slabs or tiles in wooden frames lined with sheet iron, previously smeared over with common lime mortar, in order to prevent adhesion to the moulds, which, being, in moveable pieces, are easily dismounted so as to turn out the cake of artificial bituminous stone. This cement is manufactured upon a great scale in many places, and used for making Italian terraces, covering the floors of balconies, flat roofs, water reservoirs, water conduits, &c. When laid down, the joints must be well run together with hot irons. The floor of the terrace should be previously covered with a layer of Paris plaster or common mortar, nearly an inch thick, with a regular slope of one inch to the yard. Such bituminous cement weighs 144 pounds the cubic foot; or a foot of square surface, one inch thick, weighs 12 pounds. Sometimes a second layer of these slabs or tiles is applied over the first, with the precaution of making the seams or joints of the upper correspond with the middle of the under ones. Occasionally a bottom bed, of coarse cloth or gray paper, is applied. The larger the slabs are made, as far as they can be conveniently transported and laid down, so much the better. For *hydraulic* cements, see MORTAR.

An excellent cement for resisting moisture is made by incorporating thoroughly eight parts of melted glue, of the consistence used by carpenters, with four parts of linseed oil, boiled into varnish with litharge. This cement hardens in about forty-eight hours, and renders the joints of wooden cisterns and casks air and water tight. A compound of glue with one-fourth its weight of Venice turpentine, made as above, serves to cement glass, metal and wood, to one another. Fresh-made cheese curd, and old skim-milk cheese, boiled in water to a slimy consistence, dissolved in a solution of bicarbonate of potash, are said to form a good cement for glass and porcelain. The gluten of wheat, well prepared, is also a good cement. White of eggs, with flour and water well-mixed, and smeared over linen cloth, forms a ready lute for steam joints in small apparatus.

White lead ground upon a slab with linseed oil varnish, and kept out of contact of air, affords a cement capable of repairing fractured bodies of all kinds. It requires a few weeks to harden. When stone or iron are to be cemented together, a compound of equal parts of sulphur with pitch answers very well.

Mr. Joseph Gibbs, a practical civil engineer of eminence, obtained a patent in May, 1850, for improvements in artificial stone, mortar and cements, and in the modes of manufacturing the same, of which the following abstract is worthy of attention.

"The several descriptions of Roman cement are made from the septaria of either Harwich or Sheppey, or from the septaria of the lias formation, or from beds of cement stone found in the upper division of the lias formation, or in the shale beds of the Kimmeridge clay. All these stones, when manufactured, produce a material of a dark brown colour, unfit for incrusting buildings so as to imitate stone, unless they are either coloured by washes, or by painting. Now, amongst the advantages to be obtained from the cements and mortars I have invented is this, that every description of freestone may be exactly imitated without any wash or painting whatsoever being applied.

"Again, the cement called Portland cement is made by mixing clay and chalk, or river mud and chalk, in such proportions together that the combined materials may contain about the same proportions of lime, silica, and alumina, as are found in cements. These materials are ground together in water to a great degree of fineness. After subsidence, and also after obtaining the proper consistency, the pasty materials are dried in kilns, or otherwise, and afterwards burned like ordinary cements in calcining kilns. The materials are then ground in proper mills. To these materials, so prepared and so ground, are added from one-third to one-half of their weight in slag of copper smelting, or other furnaces, or the slag of over-burnt cement, which, combining with the lime and silica, forms a cement which is much nearer the colour of stone than any of the Roman cements heretofore made. Now, as the combination of chalk and clay, or river mud, is expensive when manufactured, and causes these cements to be very dear; and further, as the materials are only combined mechanically and not chemically, there is neither uniformity in their quality, nor can reliance be always placed on their stability; the object of my invention, therefore, is to lessen the expense of manufacturing artificial stone, mortars, and cements, and produce a superior quality of cement to those now in use.

"My invention divides itself into three parts; the first of which relates to mortar and cements, the second to the manufacture of artificial stone, and the third to the modes of manufacturing the said mortar cements, and artificial stone.

"I have found by research, analysis, and much experience, that there exists in nature vast beds of argillaceous marls and marly limestones, or marl stones, which contain the due admixture of lime, silica, and alumina, from which hydraulic cements and artificial stone may be manufactured. The principal places for finding this marl and marly limestone (geologically speaking) are the chalk formation, the Wealden formation, the Purbeck beds, the lias formation, the mountain limestone, and the lowest strata of the coal measures. In the chalk formation, the marl will be found immediately at the junction of chalk with and just above the green sand; in that division of the sand usually called 'gault,' or at such places where the fire-stone (or, as it is sometimes called, the 'malen rock') exists, interposing between the gault and the chalk marl. This chalk marl possesses a varying character, increasing in the amount of silica and alumina as it approaches either the malen rock or the gault; in fact, sometimes when there is no malen rock (or fire-stone) the gault becomes a calcareous marl, charged with sufficient lime to make a cement, but the amount of silica and alumina, and lime composing the marl, can only be ascertained by experiment. The upper beds of marl, and those nearest to the greystone rock of the chalk formation, will make hydraulic mortar quite equal, and often superior, to the best lias lime; and the lower beds will make cement equal to Roman cement, except that it does not contain a very noticeable quantity of either manganese or iron; consequently it is of light stone colour when manufactured, and is better adapted to cover buildings, and represent stone. The chalk marl may readily be found by the springs of water which issue from the back or escarpment face of the chalk formation, and above these springs (but in close proximity thereto) the hydraulic lime will be found, and below the springs the materials for making cement must be extracted.

"The proper place for obtaining the marly limestone in the Wealden formation is in what are termed by geologists the Ashburnham beds, above and below and in immediate contact with the Ashburnham limestone. These limestone marls are like perfect limestone when first extracted, but decompose by exposure to the air after a short time. The limestone itself, in particular localities, sometimes become a cement-stone or marl stone, which may be known by its not slackening in water after calcination.

"The material for making cement out of the beds of Purbeck limestone is obtained from some of the partings which divide the ordinary Purbeck beds of limestone, and is exceedingly well calculated to make a cement of great purity and whiteness, but all the beds do not contain in their partings the quality desired, but the proper material may be readily found by noticing the decomposing character of the shale when exposed to the air.

"The materials which I extract from the lias formation, locally called 'rummell' at the lime quarries at Barrow-on-Soar, in Leicestershire, is an especial bed of marly limestone, found above and separated from all the lias beds of limestone in that district. The same bed of 'rummell' is found in other districts of the lias formation, and may be readily observed on the coast of Dorsetshire, near Lyme Regis. It is seen on the face of the limestone cliffs, imbedded in a marly shale, the whole of which decomposes on exposure to the air. This bed of 'rummell' has no local name in the district of Lyme Regis, not having hitherto been applied to any useful purpose; but it may be easily found, as it exists in a deep bed of shale between the lias limestone beds and the beds of cement stone which heretofore have been worked, and are so now (but the cement from this last-named stone is of a deeper brown colour, and unfit for imitating stone, whilst the bed of 'rummell' will make a cement of a light colour exactly like freestone).

"In some cases, as when I use the hardening materials (to be hereafter described) in combination with the calcareous marls from the lias formation, I use some of the partings of calcareous shale existing between the lias beds of workable limestone, provided such calcareous partings or shale beds contain sufficient lime, which shale, after calcination, I combine with the hardening material, in the manner hereafter to be directed, either by itself or in combination with the 'rummell' of this formation along with the hardening materials.

"The materials which I extract to make cements from the mountain or carboniferous limestone are only found in the upper part of that great deposit, and must be sought for in or at the immediate junction of the limestone shale (which shale lies under the mill-stone grit, and above the mountain or carboniferous limestone, dividing the two formations). These materials consist of mountain limestone, limestone shale, and bastard limestone (that is, the limestone which will not slack after calcination, but still retains its shape after being dipped in water). These two materials are found above the beds of workable limestone, which beds are wrought for making ordinary limes (the shales and the bastard limestone, or limestone marl, being always found together). These shales produce a dark cement, but the bastard limestone produces a cement of a light stone colour, and therefore more fit for imitating stone.

"In addition to these substances, I extract from this formation sparry iron stone, to make hardening materials with.

"The materials which I extract from the coal measures for making cement, or for mixing with the other cementitious materials, are found only in the lowest beds of the coal measures, often connected with the last two seams of coal, and before that

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stratum the millstone grit. These cementitious materials consist, first, of the coal shale (called metals by miners), and round septaria nodules (boilams by the local miners about Congleton in Cheshire). The 'metals' will not in all cases make cement, but most of them in contact with the boilams (or septaria balls) will do so. These boilams are composed chemically of sulphur, lime, iron, and manganese, and are therefore easily distinguishable; they are, in fact, a species (as well as the 'metals') of pyrites. The 'metals' and the septaria balls make excellent cement, of great hardness, but of dark colour. I use, however, this cement, as well as other materials, in mixing with some of the cements I have before specified, to give them hardness—the process of doing which, and the nature of the materials, will be described hereafter—such materials will be called hardening materials.

"When any of the materials just enumerated are to be made into cements, the usual course of proceeding for making cements is to be followed; that is, by burning in kilns and grinding in mills, in the way cement is now manufactured; but I recommend that the marls and marl stones be first dried in kilns or ovens, at a heat fit for baking, until all moisture be driven off, and that then the calcination be prolonged as much as possible, but that the heat be kept so low as is only just sufficient to effect complete calcination,—this being indispensable, to avoid the commencement of vitrification, which would destroy the adhesive properties of the cement. These observations will be found equally applicable to kilns, such as are now in use, or to the kiln of the improved description, to be described hereafter, and which forms part of this invention.

"Although I have described certain new materials for making cements and mortars therefrom, and such materials are capable of forming good cements without any admixture whatever, yet, in some cases, I make a composition of the various cements to obtain particular qualities; thus, for instance, I take a quantity of the pyrites septaria, called boilams, and mix it with an equal quantity of the chalk marl before described. In this case the chalk marl keeps the colour light, and the septaria or boilams of the coal measures before described give to the chalk marl a considerable degree of hardness. I also make a mixture of equal parts of the bastard limestone before described for a like purpose, and with the same result; but with the 'rummells' of the lias formation before described, or the rich argillaceous shale of that formation, not more than one-third or one-quarter part by weight of the septaria or boilams is needful to give great hardness and strength to the cement made therefrom. The same observation applies to the cement stone of the Ashburnham beds already described, as well as the cement made from the interposing Purbeck shale partings.

"But in many cases a cement is required of a hardness beyond what would be afforded from either of the cement stones I have described, or the mixture of two or more of them together; and in these cases I use substances to be combined with any of these cement stones or their mixtures, which I have called 'hardening materials.' These materials (in addition to the one I have described, namely, the pyritous septaria or boilams) consist—

"First: Of the slag or cinder derivable from iron blast furnaces.

"Secondly: Slag from puddle furnaces, or from reheating or mill furnaces.

"Thirdly: Slag derivable from copper, lead, or tin furnaces, or the slag from cement kilns.

"Fourthly: The sparry iron of the carboniferous strata.

"Fifthly: The pyritous earth known by geologists as Folkestone pyrites, which pyritous earth is a thin lamina, or bead, or band of earth, in concretions just below the gault strata, and which it separates from the rock and sand bed just below the gault. The pyrites may be found in other places in similar positions; but the locality just indicated, namely, Folkestone in Kent, will be a sufficient guide to find a similar material elsewhere. This pyritous earth may be calcined in ordinary lime kilns, the same as the cement stones I have before enumerated. If this pyrites be mixed with chalk marl or any other of the white cement stones I have before mentioned, the imitation of stone will be very exact, and may be sculptured afterwards with the same facility as ordinary freestone. The same effect may be produced by mixing in the like proportions this calcined pyritous earth with the artificial hydraulic cements now commonly made (and which cements are composed of chalk and clay, or mud, in due proportions, and ground together before calcination), the pyritous earth or Folkestone pyrites displacing in this case the ground slag with which such cements are now usually combined.

"The various slags and cinders require only to be ground under edgestones to a fine powder, and then to be mixed with any of the various cements I have enumerated, namely, the cement from the chalk, the cement from the lias, the cement from the Wealden and Purbeck beds, the cement from the mountain limestone, and the cement from the coal measures; these mixtures must be effected by sifting the materials together, or by some other mode which will effectually incorporate and combine them; and the quantities may be generally from one quarter (by weight) to one of slag, mixed with one of calcareous cement.

"In some cases I grind pyritous septaria of the coal measures, or other equivalent materials (having the same chemical properties), into a fine powder, and mix such powder with about its equal weight of some of the calcareous marls after they are made into cement, instead of mixing such marls with the slags, or with the calcined pyrites of Folkestone, as before directed. In other cases, I mix with the cement made from chalk or other marls an equal weight of any of the cements now in use, or of the calcined septaria of the London clay basin, called Roman cement stone, more especially that part of it which is called sandstone; but in the case of using any of the septaria of the London clay, the marl and the stone may be calcined, and ground together in equal proportions, or thereabouts.

"Claims:—1st. The manufacture of mortar and cement from chalk marls, the calcareous marls of the Ashburnham beds, the calcareous shales of the Purbeck formation, the rummell beds of the lias formation, the calcareous and mountain limestome shales, bastard limestone and the 'metals,' and pyritous septaria of the coal formation, all or any of them, when prepared for the purpose by grinding or pounding, and by treating with water as described, and whether the same are combined or not combined with certain hardening materials (afterwards specified), or other cementitious substances.

"2. The use of the 'hardening materials' described, when used in combination with any of the calcareous substances enumerated in the preceding claim, or in combination with any other natural calcareous marl or marlstones.

"3. The use of the calcined Folkestone pyritous earth, the sparry ironstone or white ironstone of the mountain limestone, and the calcined pyritous septaria of the coal measures, as 'hardening materials' in combination with any artificially-formed cement composed of chalk, or lime and clay, ground and calcined in the manner now usually practised for manufacturing artificial cements.

"4. The mixture of any of the before described marls or marlstones, or pyritous septaria, from the coal measures, with each other, or with any of the water cements or limes now in use, or the materials of which the same are composed.

"5. A particular process of grinding and pounding cement and materials mixed therewith, as described.

"6. The consolidation of cement and materials mixed with such cement by concussion, for forming blocks or other solid shapes in moulds.

"7. A process of making artificial stone by putting plastic materials between lattices or other convenient forms; and also certain methods of casting hollow parallelograms in cement, to be afterwards filled up with concrete, for walls of artificial stone.

"8. The use of a kiln, with fire-vaults under the whole area of such kiln, such vaults communicating with each other in various directions through spaces between the bricks composing such vaults.

"9. The use of a brick with projections for constructing fire-vaults, as described, for calcining marls, marlstones, cements, and other materials used for making metallic mortars.

"10. The use of a circular or continuous kiln, for the purpose of making mortars and cements."

CERASIN. The name given by Dr. John to those gums which swell, but do not dissolve in water; such as gum tragacanth. It is synonymous with BASSORINE, which see.

CERATE, from *cera, wax.* An unguent, of rather a stiff consistence, made of oil, or lard and wax, thickened occasionally with pulverulent matters.

CERINE. A substance which forms from 70 to 80 per cent. of bees'-wax. It may be obtained by digesting wax, for some time, in spirits of wine, at a boiling temperature. The *myricine* separates, while the *cerine* remains dissolved, and may be obtained from the decanted liquor by evaporation. Cerine is white, analogous to wax, fusible at 134° F., hardly acted upon by hot nitric acid, but is readily carbonized by hot sulphuric acid. When treated with caustic alkaline lye, it is converted into margaric acid and *ceraïne.*

CERIUM. A peculiar metal discovered in the rare mineral, called *cerite*, found only in the copper mines of Bastnaes, near Riddarhytta, in Sweden. Cerium extracted from its chloride by potassium, appears as a dark red or chocolate powder, which assumes a metallic lustre by friction. It does not conduct electricity well, like other metals; it is infusible; its specific gravity is unknown. It has been applied to no use in the arts.

CERUSE. A name of white lead. See LEAD and WHITE LEAD.

CETINE. The name given by Chevreul to spermaceti.

CHAINWORK is a peculiar style of textile fabric, to which hosiery and tambouring belong. See HOSIERY.

CHALK. (*Craie*, Fr.; *Kreide*, Germ.) A friable carbonate of lime, white, opaque, soft, dull, or without any appearance of polish in its fracture. Its specific gravity varies from 2·4 to 2·6. It usually contains a little silica, alumina, and oxide of iron. It may be purified by trituration and elutriation. The siliceous and ferruginous matters subside first, and the finer chalky particles floating in the supernatant liquid may be decanted with it, and obtained by subsidence. When thus purified, it is called *whitening* and Spanish white, in England; *schlemmkreide*, in Germany; *blanc de Troyes*, and *blanc de Meudon*, in France. Pure chalk should dissolve readily in dilute muritaic acid, and the solution should afford no precipitate with water of ammonia.

CHALK-*black*. A mineral, called also *drawing-slate*.

CHALK-*French*. *Steatite*, or soap-stone; a soft magnesian mineral.

CHALK-*red*. A clay coloured with the peroxide of iron, of which it contains about 17 per cent.

CHALYBEATE is the name given in medicine to preparations of iron. The most agreeable, and one of the most powerful, forms of such medicines, is the improved chalybeate water, for which Mr. Henry Bewley, apothecary in Dublin, obtained a patent in June, 1842. The following is his valuable recipe:—Eight ounces of crystallized citric acid being dissolved in about four times their weight of water, heated to 170° F., are saturated with pure peroxide of iron, in the washed state, after being precipitated by ammonia from the ferric sulphate. The solution is sweetened, flavoured, and charged highly with carbonic acid gas, so as to make a very palatable potion, agreeable also to the stomach.

I find by analysis that 100 parts of Mr. Bewley's brilliant citrate of iron contain 28·9 of peroxide, 48·5 of citric acid, and 23 of water; and that a six-ounce phial of his chalybeate water contains of that citrate a quantity equivalent to nearly 8 grains of peroxide of iron.

Similar compounds are also specified to be made with other organic salts, as the tartrate or lactate of iron.—*Newton's Journal*, xxii. 470.

CHAMELEON MINERAL. As this compound—so long known in chemistry as a mere curiosity, on account of the surprising changes of color which it spontaneously assumes—has of late been largely employed for whitening tallow, palm oil, and decoloring other organic matters, it merits description in this dictionary. It exists in two states; one of which is called by chemists the manganate of potash, and the other the oxymanganate; denoting that the first is a compound of manganic acid with potash, and that the second is a compound of oxymanganic acid with the same base. They are both prepared in nearly the same way; the former by calcining together, at a red heat in a covered crucible, a mixture of one part of the black peroxide of manganese with three parts of the hydrate of potash (the fused potash of the apothecary). The mass is of a green color when cold. It is to be dissolved in cold water, and the solution allowed to settle, and become clear, but by no means filtered for fear of the decomposition to which it is very prone. When the decanted liquid is evaporated under the exhausted receiver of an air-pump, over a surface of sulphuric acid, it affords crystals of a beautiful green color, which should be laid on a clean porous brick to drain and dry. They may be preserved in dry air, but should be kept in a well-corked bottle. They are decomposed by water, but dissolve in weak water of potash. On diluting this much, decomposition of the salt ensues, with all the chameleon changes of tint; red, blue, and violet. Sometimes a green solution of this salt becomes red on being heated, and preserves this color even when cold, but resumes its green hue the moment it is shaken: it might, therefore, furnish the crafty votaries of St. Januarius with an admirable means of mystifying the worshippers at his shrine. The original calcined mass, in being dissolved, always deposites a considerable quantity of a brown powder, which is a compound of the acid and peroxide of manganese combined with water. Much of the potash remains unchanged, which may be recovered.

The oxymanganate of potash is made by fusing, with a strong heat, a mixture of equal parts of peroxide of manganese and hydrate of potash, or one part of peroxide and two parts of nitre. The mass is to be dissolved in water, and, if the solution be green, it should be reddened by the cautious addition of a few drops of nitric acid. The clarified liquor is to be evaporated to the point of crystallization. Even the smallest crystals of this salt have such an intense red color, that they appear black with a green metallic reflection. In the air they gradually assume a steel gray hue, without undergoing any essential change of nature. A very little of the salt reddens a large body of water. The least portion of any organic matter added to the solution of this salt reduces the oxymanganic acid to the state of peroxide, which precipitates combined with water; and the liquor becomes green or colorless, according to circumstances.

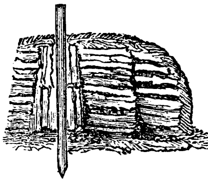
A more permanent oxymanganic salt may be made as follows:—Melt chlorate of potash over a spirit lamp, and throw into it a few pieces of hydrate of potash, which immediately dissolve and form a limpid liquid. When peroxide of manganese in fine powder is gradually introduced into that melted mixture, it immediately dissolves, with the production of a rich green colour. After adding the manganese in excess, the whole is to be exposed to a gentle red heat, in order to decompose the residuary chlorate of potash. It is now a mixture of manganate of potash, chloride of potassium and peroxide of manganese. It forms with water a deep green-coloured solution; which when boiled assumes a fine red colour, in consequence of its becoming an oxymanganate, and it ought to be decanted off the sediment while hot. By cooling, and still more after further evaporation, the oxymanganate of potash separates in crystals possessed of great lustre; but towards the end colourless crystals of chloride of potassium.

Both the above salts are readily decomposed by organic bodies and other combustibles, whereby they have their acid converted into an oxide, with the disengagement of oxygen, and the destruction of many vegetable and animal colours. In this respect they resemble the nitrates and chlorates.

CHARCOAL. The fixed residuum of vegetables exposed to ignition out of contact of air. In the article CARBON, I have described the general properties of charcoal and the simplest mode of making it. I shall here detail the best systems of manufacturing this product upon the continent of Europe.

To carbonize wood under a moveable covering, the plan of *meiler*, or heaps, is employed very much in Germany. The wood is arranged either in horizontal layers, or in nearly vertical ones, with a slight slope, so as to form conical rounded heaps of different sizes. The former are called lying *meiler*, *fig.* 339; the latter standing *meiler*, *figs.* 340 and 341.

340



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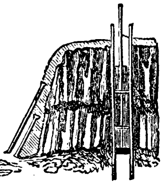

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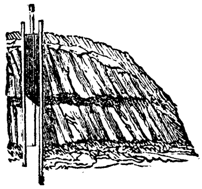

Both are distributed in much the same way.

In districts where the wood can be transported into one place by means of rivers, or mountain-slides, a dry flat space must be pitched upon, screened from storms and floods, which may be walled round, having a slight declivity made in the ground, toward the centre. See *fig.* 342. Into this space the tarry acid will partially fall, and may be conducted outward, through a covered gutter beneath, into a covered tank. The mouth of the tank must be shut, during the coaking, with an iron or stone slab, luted with clay. A square iron plate is placed over the inner orifice of the gutter, to prevent it being choked with coal ashes. *Fig.* 342 represents a walled *meiler* station; *a*, the station; *b*, the gutter; *c*, the tank, which is covered with the slab *d*; *e*, a slab which serves to keep the gutter clear of coals. The cover of the heaps is formed of earth, sand, ashes, or such other matter as may be most readily found in the woods. They should be kindled in the centre. From 6 days to 4 weeks may be required for charring a heap, according to its size; hard wood requiring most time; and the slower the process, the better and greater is the product, generally speaking.

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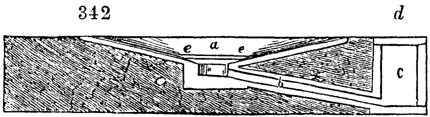

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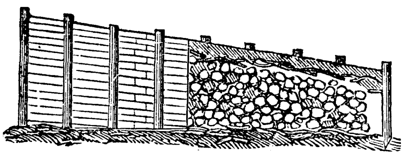

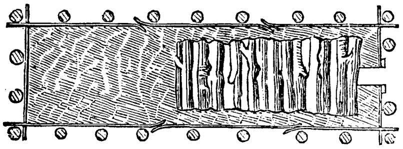

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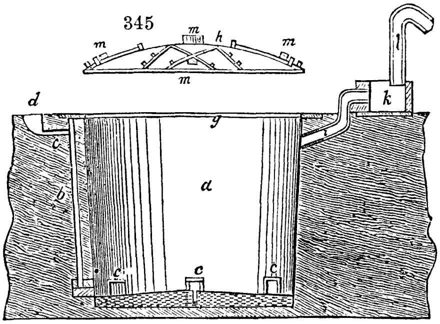
Charring of wood in mounds (*Haufe* or *liegende werke*), *figs.* 343 and 344, differs from that in the *meiler*, because the wood in the *haufe* is successively charred, and the charcoal is raked out by little and little. The product is said to be greater in this way, and also better. Uncleft billets, 6 or 8 feet long, being laid over each other, are covered with ashes, and then carbonized. The station is sometimes horizontal, and sometimes made to slope. The length may be 24 feet, the breadth 8 feet; and the wood is laid crosswise. Piles are set perpendicularly to support the roof, made of boughs and leaves, covered with ashes. Pipes are occasionally laid within the upper part of the mounds, which serve to catch and carry off some of the liquid products into proper tanks.

345



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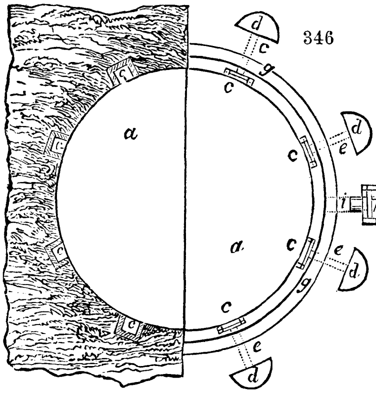

Fig. 345 is a vertical section, and *fig.* 346, a half bird's-eye view, and half cross section, at the height of the pit-bottom, of Chabeaussiere's kiln for making wood charcoal. *a* is the oven; *b*, vertical air-pipes; *c c*, horizontal flues for admitting air to the kiln; *d d*, small pits which communicate by short horizontal pipes *e e*, with the vertical ones; *f*, the sole of the kiln, a circle of brickwork, upon which the cover or hood *h* reposes; *i*, a pipe which leads to the cistern *k*; *l*, the pipe destined for carrying off the gaseous matter; *m m*, holes in the iron cover or lid.

The distribution of the wood is like that in the horizontal *meilers*, or heaps; it is kindled in the central vertical canal with burning fuel, and the lid is covered with a few inches of earth. At the beginning of the operation all the draught flues are left open, but they are progressively closed, as occasion requires. In eight kilns of this kind, 500 *decasters* of oak wood are carbonized, from which 16,000 hectolitres of charcoal are obtained, equal to 64,000 pounds French, being about 25 per cent.; besides tar and 3000 velts of wood vinegar, of from 2° to 3° *Baumé*.

At Crouy upon the Ourcq, near Meaux, there is a well-constructed kiln for making turf-charcoal. It resembles most nearly a tar-kiln. In *fig.* 347, *a* is the cylindrical coaking place, whose surrounding walls are heated by the flame which passes through the intermediate space *b*. The place itself is divided by partitions of fire tiles into three stages, through the apertures in which the flames of the fire *c c*, rise, and heat the exterior of the coaking apartment. In order to confine the heat, there is in the enclosing walls of the outer kiln a cylindrical hollow space *d*, where the air is kept stagnant. Through the apertures left in the upper end at *e*, the turf is introduced; they are then shut with an iron plate *f*, which is covered with ashes or sand. The fire-place opens above this aperture, and its outlet is provided with a moveable iron cover *g*, in which there is a small hole for the issue of the gases. The sole of the kiln consists of a cast iron slab *h*, which may be raised by means of a hook *i* upon it. This is drawn back after the carbonization is completed, whereby the charcoal falls from the coaking space into a subjacent vault. The volatile products are carried off by the pipe *k*, and led into the condensing cistern; the gases escaping to the fire-place where they are burned. The iron slab is protected from the corrosion of the acid vapors by a layer of coal ashes.

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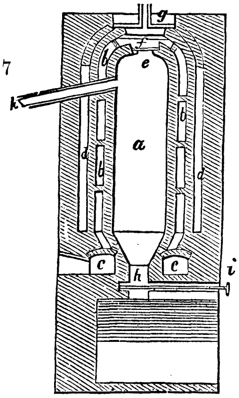

CHASCHISCH. Hadschy is not the correct term for this narcotic drug, for Hadschy means a *pilgrim;* the true name is, according to pronunciation, *Chaschisch*, the Arab word for hemp (*Cannabis sativa*). By this name all intoxicating drugs, whose chief constituent is this herb, are well known over the whole of the East. The mode of preparing chaschisch is the following:—

The tops and all the tender parts of the hemp plant are collected after the period of inflorescence, dried and kept for use. It must be premised that the hemp plant is in the East distinguished by its narcotic properties, although botanists are unable to detect any difference between this and the European species. The dried hemp, or chaschisch, is used—

1st. Boiled in fat, butter, or oil, with a little water; the filtered product is employed in all kinds of pastry.

2nd. Powdered for smoking: 5 or 10 grs. of the powder are smoked from a common pipe (*tsubuk*) with ordinary tobacco (*tütüm*), or from a water pipe (*nargiele*) with another kind of tobacco (*tombeki*). The tombeki is probably the leaf of a species of Lobelia; it is smoked in a nargiele, and is uncommonly narcoctic; so much so, that it is ordinarily steeped in water for a few hours before it is used to weaken it, and the pipe is charged with it whilst it is yet wet.

3rd. Formed with tragacanth mucilage into pastiles, which are placed upon a pipe and smoked in similar doses. These two last preparations are so termed *esrar* (*esrar* is the Arab word for "*secret*"); they are the most active of all the preparations of chaschisch, and the first pipe will cause cerebral congestion in beginners.

4th. Made into an electuary with dates or figs and honey. This preparation is of a dark brown, almost black, colour, and tastes of dates and hemp; it is less active than the esrar.

5th. Lastly, another electuary is prepared of the same ingredients with the addition of spices, clove, cinnamon, pepper, amber, and musk. This preparation is used as an aphrodisaic.

Chaschisch is said not to produce stupor but the most pleasant species of intoxication. The person under its influence feels with perfect consciousness in the best of all humours; all impressions from without produce the most grateful sensations; pleasant illusions pass before his eyes, and he feels comfortably happy; he thinks himself the happiest man on earth, and the world appears to him Paradise. From this imaginative state he passes into the every day state, with a perfect recollection of all sensations, and of every thing he has done and of every word he has spoken. The effects of a continued use of the narcotic are emaciation and nervous debility.

CHEESE (*composition of*). Cheese of certain dairies and districts is apt to undergo a remarkable decomposition whereby valerianic acid is formed. Messrs. Jljenko and Laskowsi distilled along with water a turbid ammoniacal liquor, which being redistilled along with some sulphuric acid, and the product neutralized by barytes, the resulting saline compound proved to be the valerianate of that base, mixed with compounds of butyric acid, caproic acid, caprylic acid, and capric acid. The cheese was from Limbourg. Valerianic acid was found by M. Balard in the cheese of Roquefort.

CHICA is a red colouring principle made use of in America by some Indian tribes to stain their skins. It is extracted from the *bignonia chica* by boiling its leaves in water, decanting the decoction, and allowing it to settle and cool, when a red matter falls down, which is formed into cakes and dried. This substance is not fusible, and when burned, diffuses the same odor as animal bodies do. It is insoluble in cold water, very soluble in alcohol and ether, but after the evaporation of these liquids, it is recovered unchanged. Fats and unctuous oils both dissolve it. It is soluble in carbonated and caustic alkaline leys, from which it is precipitated by the acids without alteration. An excess of alkali, however, speedily decomposes it. Nitric acid transforms it into oxalic acid, and a bitter matter. Chlorine makes it white.

The savages mix this pigment with the fat of the cayman or alligator, and rub their skins with the mixture. It may probably be turned to account in the arts of civilized nations.

CHIMNEY. (*Cheminée*, Fr.; *Schornstein*, Germ.) Chimney is a modern invention for promoting the draught of fires and carrying off the smoke, introduced into England so late as the age of Elizabeth, though it seems to have been employed in Italy 100 years before. The Romans, with all their luxurious refinements, must have had their Epicurean cookery placed in perpetual jeopardy from their kitchen fires, which, having no vent by a vertical tunnel in the walls, discharged their smoke and frequently their flames at the windows, to the no small alarm of their neighbors, and annoyance of even the street passengers.

Chimneys in dwelling houses serve also the valuable purpose of promoting salubrious circulation of air in the apartments, when not foolishly sealed with anti-ventilating stove-chests.

The first person who sought to investigate the general principles of chimney draughts, in subserviency to manufacturing establishments, was the celebrated Montgolfier. As the ascent of heated air in a conduit depends upon the diminution of its specific gravity, or, in other words, upon the increase of its volume by the heat, the ascensional force may be deduced from the difference between the density of the elastic fluid in the interior of the chimney, and of the external air; that is, between the different heights of the internal and external columns of elastic fluid supposed to be reduced to the same density. In the latter case, the velocity of the gaseous products of combustion in the interior of the chimney is equal to that of a heavy body let fall from a height equal to the difference in height of the two aerial columns.

To illustrate this position by an example, let us consider the simple case of a chimney of ventilation for carrying off foul air from a factory of any kind; and suppose that the tunnel of iron be incased throughout with steam at 212 degrees Fahr. Suppose this tunnel to be 100 yards high, then the weight of the column of air in it will be to that of a column of external air 100 yards high, assumed at 32° F., inversely as its expansion by 180°; that is, as 1000 is to 1·375; or as 72·727 is to 100. The column of external air at 32° being 100 yards, the internal column will be represented by 72·727; and the difference$=27{\cdot}27$, will be the amount of unbalanced weight or pressure, which is the effective cause of the ventilation. Calculating the velocity of current due to this difference of weight by the well-known formula for the fall of heavy bodies, that is to say, multiplying the above difference, which is 27·27, by the constant factor 19.62, and extracting the square root of the product; thus $\sqrt{19{\cdot}62 \times 27{\cdot}27} = 23{\cdot}13$ will be the velocity in yards per second, which, multiplied by 3, gives 60·30 feet. The quantity of air which passes in a second is obtained of course by multiplying the area or cross section of the tunnel by this velocity. If that section is half a yard, that is = a quadrangle $2\frac{1}{4}$ feet by 2, we shall have $23{\cdot}13 \times 0{\cdot}5 = 11{\cdot}565$ cubic yards, $= 312\frac{1}{4}$ cubic feet.

The problem becomes a little more complicated in calculating the velocity of air which has served for combustion, because it has changed its nature, a variable proportion of its oxygen gas of specific gravity 1·111, being converted into carbonic acid gas of specific gravity 1·524. The quantity of air passed through well constructed furnaces may, in general, be regarded as double of what is rigorously necessary for combustion, and the proportion of carbonic acid generated, therefore, not one half of what it would be were all the oxygen so combined. The increase of weight in such burned air of the temperature of 212°, over that of pure air equally heated, being taken into account in the preceding calculation, will give us about 19 yards or 57 feet per second for the velocity in a chimney 100 yards high incased in steam.

Such are the deductions of theory; but they differ considerably from practical results, in consequence of the friction of the air upon the sides of the chimneys, which varies likewise with its form, length, and quality. The direction and force of the winds also exercise a variable influence upon chimney furnaces differently situated. In chimneys made of wrought iron, like those of steamboats, the refrigeration is considerable, and causes a diminution of velocity far greater than what occurs in a factory stalk of well built brick work. In comparing the numbers resulting from the trials made on chimneys of different materials and of different forms, it has been concluded that the obstruction to the draught of the air, or the deduction to be made from the theoretical velocity of efflux, is directly proportional to the length of the chimneys and to the square of the velocity, and inversely to their diameter. With an ordinary wrought-iron pipe, of from 4 inches to 5 inches diameter, attached to an ordinary stove, burning good charcoal, the difference is prodigious between the velocity calculated by the above theoretical rule, and that observed by means of a stop-watch, and the ascent of a puff of smoke from a little tow, dipped in oil of turpentine thrust quickly into the fire. The chimney being 45 feet high, the temperature of the atmosphere 68° Fahr., the velocity per second was,—

Trials.	By theory.	By experiment.	Mean temperature of chimney.
1	26.4 feet	5 feet	190° Fahr.
2	29·4	5·76	214
3	34·5	6·3	270

To obtain congruity between calculation and experiment, several circumstances must be introduced into our formulæ. In the first place, the theoretical velocity must be multiplied by a factor, which is different according as the chimney is made of bricks, pottery, sheet iron, or cast iron. This factor must be multiplied by the square root of the diameter of the chimney (supposed to be round), divided by its length, increased by four times its diameter. Thus, for pottery, its expression is $2{\cdot}06\sqrt{\frac{\mathrm{D}}{\mathrm{L}+\mathrm{D}}}$; D being the diameter, and L the length of the chimney.

A pottery chimney, 33 feet high, and 7 inches in diameter, when the excess of its mean temperature above that of the atmosphere was 205° Fahr., had a pressure of hot air equal to 11·7 feet, and a velocity of 7·2 feet per second. By calculating from the last formula, the same number very nearly is obtained. In none of the experiments did the velocity exceed 12 feet per second, when the difference of temperature was more than 410° Fahr.

Every different form of chimney would require a special set of experiments to be made for determining the proper factor to be used.

This troublesome operation may be saved by the judicious application of a delicate differential barometer, such as that invented by Dr. Wollaston; though this instrument does not seem to have been applied by its very ingenious author in measuring the draughts or ventilating powers of furnaces.

If into one leg of this differential syphon water be put, and fine spermaceti oil into the other, we shall have two liquids, which are to each other in density as the numbers 8 and 7. If proof spirit be employed instead of water, we shall then have the relation of very nearly 20 to 19. I have made experiments on furnace draughts with the instrument in each of these states, and find the water and oil syphon to be sufficiently sensible; for the weaker draughts of common fire-places the spirits and oil will be preferable barometric fluids.

To the lateral projecting tube of the instrument, as described by Dr. Wollaston, I found it necessary to attach a stop-cock, in order to cut off the action of the chimney, while placing the syphon, to allow of its being fixed in a proper state of adjustment, with its junction line of the oil and water at the zero of the scale. Since a slight deviation of the legs of the syphon from the perpendicular changes very considerably the line of the level, this adjustment should be made secure by fixing the horizontal pipe tightly into a round hole, bored into the chimney stalk, or drilled through the furnace door. On gently turning the stop-cock, the difference of atmospherical pressure corresponding to the chimney draught, will be immediately indicated by the ascent of the junction line of the liquids in the syphon. This modification of apparatus permits the experiment to be readily rectified by again shutting off the draught, when the air will slowly re-enter the syphon; because the projecting tube of the barometer is thrust into the stop-cock, but not hermetically joined; whereby its junction line is allowed to return to the zero of the scale in the course of a few seconds.

Out of many experiments made with this instrument, I shall content myself with describing a few, very carefully performed at the breweries of Messrs. Trueman, Hanbury, and Buxton, and of Sir H. Meux, Bart., and at the machine factory of Messrs. Braithwaite; in the latter of which I was assisted by Captain Ericsson. In the first trials at the breweries, the end of the stop-cock attached to the differential barometer was lapped round with hemp, and made fast into the circular peep-hole of the furnace door of a wort copper, communicating with two upright parallel chimneys, each 18 inches square and 50 feet high. The fire was burning with fully its average intensity at the time. The adjustment of the level being perfect, the stop-cock orifice was opened, and the junction level of the oil and water rose steadily, and stood at 1¼ inches, corresponding to $\frac{1·25}{8} = 0·156$ of 1 inch of water, or a column of air 10·7 feet high. This difference of pressure indicates a velocity of 26 feet per second. In a second set of experiments, the extremity of the stop-cock was inserted into a hole, bored through the chimney stalk of the boiler of a Boulton and Watt steam-engine of twenty-horse power. The area of this chimney was exactly 18 inches square at the level of the bored hole, and its summit rose 50 feet above it. The fire-grate was about 10 feet below that level. On opening the stop-cock, the junction line rose 2¼ inches. This experiment was verified by repetition upon different days, with fires burning at their average intensity, and consuming fully 12 lbs. of the best coals hourly for each horse's power, or nearly one ton and a third in twelve hours. If we divide the number 2¼ by 8, the quotient 0·28 will represent the fractional part of 1 inch of water, supported in the syphon by the unbalanced pressure of the atmosphere in the said chimney; which corresponds to 19¼ feet of air, and indicates a velocity in the chimney current of 35 feet per second. The consumption of fuel was much more considerable in the immense grate under the wort copper, than it was under the steam-engine boiler.

In my experiments at Messrs. Braithwaite's factory, the maximum displacement of the junction line was 1 inch, when the differential oil and water barometer was placed in direct communication with a chimney 15 inches square, belonging to a steam boiler, and when the fire was made to burn so fiercely, that on opening the safety-valve of the boiler, the excess of steam beyond the consumption of the engine rushed out with such violence as to fill the whole premises. The pressure of one eighth of an inch of water denotes a velocity of draught of 23·4 feet per second.

In building chimneys, we should be careful to make their area rather too large than too small; because we can readily reduce it to any desired size, by means of a sliding register plate near its bottom, or a damper plate applied to its top, adjustable by wires or chains, passing over pulleys. Wide chimneys are not so liable as narrow ones to have their draught affected by strong winds. In a factory, many furnace flues are often conducted into one vertical chimney stalk, with great economy in the first erection, and increased power of draught in the several fires.

Vast improvements have been made in this country, of late years, in building stalks for steam boilers and chemical furnaces. Instead of constructing an expansive, lofty scaffolding of timber round the chimney, for the bricklayers to stand upon, and to place their materials, pigeon-holes, or recesses, are left at regular intervals, a few feet apart, within the chimney, for receiving the ends of stout wooden bars, which are laid across, so as to form a species of temporary ladder in the interior of the tunnel. By means of these bars, with the aid of ropes and pulleys, everything may be progressively hoisted, for the building of the highest engine or other stalks. An expert bricklayer, with a handy laborer, can in this way raise, in a few weeks, a considerable chimney, 40 feet high, 5 feet 8 inches square outside, 2 feet 8 inches inside at the base, 28 inches outside, and 20 inches inside at the top. To facilitate the erection, and at the same time increase the solidity of an insulated stalk of this kind, it is built with three or more successive plinths, or recedures, as shown in *fig.* 348. It is necessary to make such chimneys thick and substantial near the base, in order that they may sustain the first violence of the fire, and prevent the sudden dissipation of the heat. When many flues are conducted into one chimney stalk, the area of the latter should be nearly equal to the sum of the areas of the former, or at least of as many of them as shall be going simultaneously. When the products of combustion from any furnace must be conducted downwards, in order to enter near the bottom of the main stalk, they will not flow off until the lowest part of the channel be heated by burning some wood shavings or straw in it, whereby the air syphon is set agoing. Immediately after kindling this transient fire at that spot, the orifice must be shut by which it was introduced; otherwise the draught of the furnace would be seriously impeded. But this precaution is seldom necessary in great factories, where a certain degree of heat is always maintained in the flues, or, at least, should be preserved, by shutting the damper plate of each separate flue, whenever its own furnace ceases to act. Such chimneys are finished at top with a coping of stone-slabs, to secure their brickwork against the infiltration of rains, and they should be furnished with metallic conducting rods, to protect them from explosions of lightning.

When small domestic stoves are used, with very slow combustion, as has been recently proposed, upon the score of a misjudged economy, there is great danger of the inmates being suffocated or asphyxied, by the regurgitation of the noxious burned air. The smoke doctors who recommend such a vicious plan, from their ignorance of chemical science, are not aware that the carbonic acid gas, of coke or coal, must be heated 250° F. above the atmospheric air, to acquire the same low specific gravity with it. In other words, unless so rarefied by heat, that gaseous poison will descend through the orifice of the ash-pit, and be replaced by the lighter air of the apartment. Drs. Priestley and Dalton have long ago shown the co-existence of these two-fold crossing currents of air, even through the substance of stone-ware tubes. True economy of heat, and salubrity, alike require vivid combustion of the fuel, with a somewhat brisk draught inside of the chimney, and a corresponding abstraction of air from the apartment. Wholesome continuous ventilation, under the ordinary circumstances of dwelling houses, cannot be secured in any other way. Were these mephitic stoves, which have been of late so ridiculously puffed in the public prints, generally introduced, the faculty would need to be immediately quadrupled to supply the demand for medical advice; for headaches, sickness, nervous aliments, and apoplexy, would become the constant inmates of every inhabited mansion. The phenomena of the grotto of Pausilippo might then be daily realised at home, among those who ventured to recline upon sofas in such carbonated apartments; only instead of a puppy being suffocated *pro tempore*, human beings would be sacrificed, to save two penny worth of fuel *per diem*.

The figures upon the following page represent one of the two chimneys, recently erected at the Camden Town station, for the steam boilers of the two engines of 60 horse-power each, belonging to the London and Birmingham Railway company. These engines then drew their train of carriages up the inclined plane of Hampstead Hill. The chimneys were designed by Robert Stephenson, Esq., engineer to the Company, executed by William Cubitt, Esq., of Gray's Inn road, — and do equal honour to both gentlemen, being probably among the most elegant and substantial specimens of this style of architecture in the world. In the section, *fig.* 348.,

A represents a bed of *concrete*, 6 feet thick, and 24 feet square.

B, brick footings set in cement; the lower course 19 feet square.

C, Bramley-fall stone base, with a chain of wrought iron let into it.

D, a portion, 15 feet high, curved to a radius of 113 feet, built entirely of Malm paviours, (a peculiarly good kind of bricks).

E, shaft built of Malm paviours in mortar.

F, ditto, built from the inside, without exterior scaffolding.

G, the cap ornamented, (as shown in the plan alongside,) with Portland stone, the dressings being tied together with copper cramps and an iron bond.

Fig. 349. represents the mouldings of the top, upon an enlarged scale.

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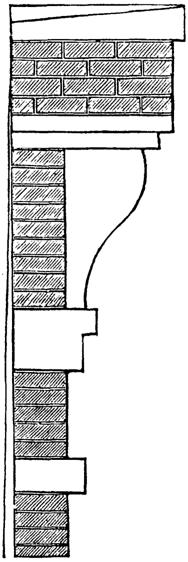
Fig. 350., a plan of the foundation, upon an enlarged scale.
Fig. 351., ditto, at the level of the entrance of the flue, as seen in
Fig. 352., the elevation of the chimney.
Fig. 353., plan at the ground level I, in *fig.* 348. and 352.
K, *fig.* 348., the lightning conducting rod.

349



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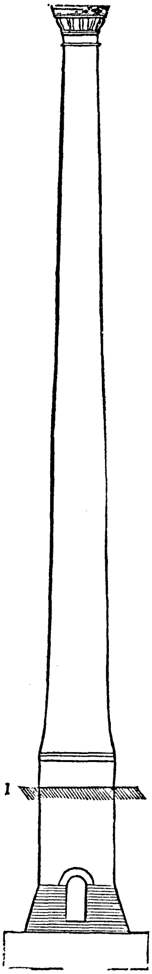

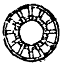

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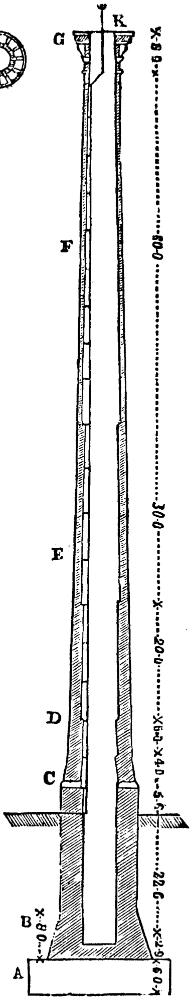

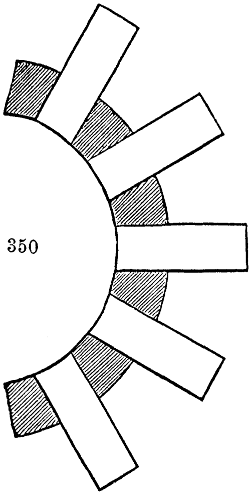

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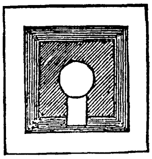

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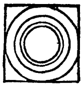

CHINA INK. (*Encre de Chine*, Fr.; *Chinesischer Tusch*, Germ.) The finest kind of this useful pigment is seldom met with in our markets. According to a description in a Japanese book, it is made from the condensed smoke or soot of burned camphor; and hence, when of the best quality, it has this odour. Most of the China ink is made from oil-lampblack occasionally disguised as to smell, with musk, or with a little camphor black. The binding substance is gelatine, commonly made from parchment or ass' skin; but isinglass answers equally well. A good imitation may be made by dissolving isinglass in warm water, with the addition of a very little alkali (soda), to destroy its gelatinizing power; and incorporating with that solution, by levigation on a porphyry slab, as much of the finest lampblack as to produce a mass of the proper consistence. The minute quantity of alkali serves also to saponify the oil which usually adheres to lampblack; and thereby to make a pigment readily miscible with water.

CHINTZ is a peculiar style of fast-printed calico, in which figures of at least five different colours are impressed upon a white or light coloured ground.

CHLORATE OF POTASH, commonly called oxymuriate of potash. This interesting saline compound has become the object of a pretty extensive manufacture, in consequence of its application to make matches for procuring instantaneous light, and a detonating powder for fire-arms. It may be prepared both in the humid and dry way.

Having made a strong solution of purified potash, or carbonate of potash, with from two to three parts of water, we pass through it in a Woulfe's apparatus a current of chlorine gas, till it ceases to absorb any more. Chloride of potash and chloride of potassium alone are formed as long as there is an excess of alkali in the solution; but afterwards, in the further reaction of the materials, the chloride passes into the state of a chlorate, and, as such, precipitates from the solution. During the first half of the operation, that is, till the potash be about one half saturated with chlorine, as indicated by litmus paper ceasing to be darkened and beginning to be blanched, only the chloride of potassium or muriate of potash falls. The process should be interrupted at this point in order to remove the salt, to wash it, to add the washings to the liquor, and then to transmit the gas freely through the solution. As the operation advances, less muriate of potash is formed, and at length nothing but the pure chlorate is separated in crystals. When finally the bubbles of gas pass through without being sensibly absorbed, the process is known to be completed; the liquid may then be allowed to settle, and be poured off from the crystals of chlorate of potash, which are purified from the muriate by dissolving them in three times their weight of boiling water, and filtering the solution while hot. On its cooling, the chlorate will separate in pearly-looking crystalline plates. It may be rendered quite pure by a second crystallization, in which state it does not affect solution of nitrate of silver.

The above potash ley usually gets a reddish tint in the course of the process in consequence of a little manganesic acid coming over with the chlorine, but it gradually loses this color as the saturation becomes complete, when the solution turns yellow. The tubes for conveying the gas should be of large diameter, if they be plunged into the saline solution, because the crystallization which takes place in it is apt to choke them up. This inconvenience may however be obviated by attaching to the end of the glass tube, a tube of caoutchouc terminated in a small glass funnel, or simply the neck of a caoutchouc bottle with a part of its body, whose width will not be readily closed with a saline crust. The residuary lixivium may be used against another operation, or it may be evaporated down to half its bulk and set aside to crystallize, whereby some more chlorate will be obtained, mixed indeed with muriate and carbonate, from which however it may be separated by a second crystallization. In general the pure chlorate obtained does not exceed one tenth the weight of the potash employed; because in thus treating potash with chlorine, five sixths of it are converted into muriate of potash and only one sixth into chlorate, and a part of the latter adheres to the muriate, or is lost in the mother waters of the crystallizations.

The chlorate of potash may be more conveniently manufactured, like that of lime, in the dry way. St. Romer patented at Vienna the following method for that purpose in 1821:—Ten pounds of crystallized peroxyde of manganese are to be finely pulverized, mixed with ten pounds of plumbago, and thirty pounds of common salt, and put into the leaden retort represented in *fig.* 355, p. 410. From the middle of the helmet-shaped lid of this vessel, a lead tube, two feet long, and two inches wide, conducts to the receiver, which is a square earthen pan, hard glazed both within and without, of the same capacity with the retort. The end of the tube must be made fast to a frame at the height of six inches above the bottom of the receiver. Upon its inner sides, four inches apart, brackets are to be fixed for supporting a series of laths or shelves of white wood, on which a number of little paper or pasteboard boxes are to be laid. In these boxes ten pounds of the purest carbonate of potash, prepared from tartar, are to be spread. The receiver must now be covered with a lid made tight by a water lute. Twenty pounds of concentrated sulphuric acid previously diluted with sixteen pounds of water, and then cooled, are to be poured upon the mixed materials in the retort, the lid immediately secured, with the tube adjusted in the receiver. The whole must be allowed to operate spontaneously without heat for twelve hours. At the end of this time the retort is to be surrounded with a water bath and steadily heated during twelve hours, and then left to cool for six hours

The apparatus must now be opened, the cakes of chlorate of potash removed, and freed from muriate by solution and crystallization.

M. Liebig proposes the following process for obtaining chlorate of potash :—

Heat chloride of lime in water till it ceases to destroy vegetable colors. In this case a mixture of chloride of calcium and chlorate of potash is obtained. This is to be dissolved in hot water, and to the solution concentrated by evaporation, chloride of potassium is to be added, and then suffered to cool. After cooling, a quantity of crystals of chlorate of potash is obtained, which are to be redissolved and crystallized again to purify them. M. Liebig considers that this will be a cheap process for obtaining chlorate of potash. From 12 ounces of chloride of lime, of so bad a quality that it left 65 per cent. of insoluble matter, he obtained an ounce of chlorate of potash.

The only difficulty to overcome in this process is, from the chloride of lime not being so easily decomposed by heat as is generally supposed; a solution of it may be kept boiling for an hour without losing its bleaching power. The best method is to form a thin paste with chloride of lime and water, and then to evaporate it to dryness. If it be required to prepare it by passing chlorine into cream of lime, it is advantageous to keep it very hot.

The chlorate of potash which separates from the solution by crystallization, has not the form of scales which it usually possesses, but is prismatic: whether this is occasioned by some admixture has not been ascertained; but on re-crystallizing, it is obtained in the usual form.

The solution ought not merely to be left to cool, in order to procure crystals, for the crystallization is far from being terminated even after complete cooling; crystals continue to be deposited for 3 or 4 days.

The following modification of the process for making chlorate of potash is that of M. Vée. A solution of chloride of lime, marking 18° or 20° Baumé, is to be set upon the fire in a lead or cast iron pot, and when it begins to get hot, there is to be dissolved in it a quantity of chloride of potassium sufficient to raise the hydrometer 3 or 4 degrees. It must be then concentrated as quickly as possible till it marks 30° or 31°, taking care that it does not boil over by the sudden extrication of oxygen. The concentrated liquor is set aside to crystallize in a cool place; where a deposite of chlorate of potash forms, mixed with chloride of potassium. The mother waters being evaporated to the density of 36°, afford another crop of crystals, after which they may be thrown away.

The salts obtained at the first crystallization are to be re-dissolved, and the solution being brought to 15° or 16° is to be filtered, when it will afford upon cooling pure chlorate of potash.

Chlorate or oxymuriate of potash has a cooling, somewhat unpleasant and nitrous taste. It does not bleach. At 60° F. 100 parts of water dissolve six parts of it, and at its boiling point or 220°, sixty parts. When heated to dull ignition in a glass retort, it gives out 39·15 per cent. of its weight of oxygen, and becomes thereby chloride of potassium. When strongly triturated in a mortar it crackles, throws out sparks, and becomes luminous. It deflagrates upon red-hot cinders like nitre: when triturated along with sulphur, or phosphorus, it detonates with great violence, not without danger to the hands of the operator, if they be not protected by a thick glove. Similar detonations may be produced with cinnibar or vermilion, sulphuret of potassium, sugar, volatile oils, &c., but they can be effected only by the smart blow of a heated hammer and anvil. A mixture of sugar or starch with chlorate of potash is readily inflamed by a drop of sulphuric acid, and this experiment is the basis of the preparation of the oxygenated matches, as they have been commonly called. The following formula forms a good paste for tipping the said matches, made of narrow slips of either wood or card. Thirty parts of the chlorate in fine powder are to be mixed gently with a spatula upon paper with ten parts of flowers of sulphur well levigated, eight of sugar, five of gum arabic, and enough of vermilion to give the whole a rose tint. We begin by mixing tenderly together the sugar, the gum, and the salt previously pulverised; we then add as much water as shall reduce the mixture to a thin paste, and lastly introduce the sulphur; after which all must be well incorporated. The points of the matches, either previously tipped with sulphur or not, are to be dipped in that paste, so as to get coated with a little of it, and are lastly laid in a warm place till they become thoroughly dry. To kindle one of them, it must be touched with strong sulphuric acid, which, for this purpose, is usually kept in a small well-stopped vial, and thickened with amianthus. Aspen is reckoned the best wood for matches.

Of late years a detonating priming for fire-arms has been much used with the percussion locks. The simplest formula for making it is to take ten parts of gunpowder, to lixiviate it with water, and to mix the residuum, while moist, with five parts and a quarter of chlorate of potash, reduced to an extremely fine powder. The paste may be made pretty thin, for the salt is sparingly soluble in cold water, and it mixes best when tolerably fluid. This powder when dry is dangerous to handle, being very apt to explode. But this danger is guarded against by letting fall a drop of the paste into each copper percussion cap, and leaving it to dry there. In the detonation of this powder, besides muriate of potash, there are generated a little sulphate of potash and chlorine gas, which rust the metal very fast. For which reason fulminate of mercury is now preferred by many sportsmen as a detonating powder. See FULMINATE.

The following ingenious and easy way of making this valuable chlorate has been lately suggested by Professor Graham:—Mix equal atomic weights of carbonate of potash and hydrate of lime (70 of the former, if pure, and 37 of slaked lime in powder), diffuse them through cold water, and transmit chlorine gas through the mixture. The gas is absorbed with great avidity, and the production of a boiling heat. When the saturation is complete, carbonate of lime remains, and a mixture of muriate and chlorate of potash, which latter salts are to be separated, as usual, by the difference of their solubility in water.

It has been remarked on the above process, that it effects no saving of potassa, and therefore is far inferior to the one long practised in several parts of Germany, especially at Giessen, and introduced into this country a good many years ago by Dr. Wagenmann, from Berlin. The chlorine is passed into a mixture of one equivalent of chloride of potassium (76), and 6 equivalents of hydrate of lime (222), previously stirred with water to the consistence of a thin paste. Thus the calcium of the lime unites with the chlorine to form chloride of calcium, while the chloride of potassium is converted into chlorate of potassa, which salt is easily separated in crystals by its sparing solubility.

Chlorate of potash may also be made by saturating with chlorine a mixture of 74 parts of chloride of potassium (muriate of potash) and 168 parts of quicklime, brought to the consistence of a thin pap by the cautious addition of water. The mass being dissolved in warm water, and evaporated and cooled, yields crystals of chlorate of potash, while a mother water of chloride of calcium (muriate of lime) remains. The following process has likewise been prescribed:—Mix 10 parts of good chloride of lime with water into a pap, and evaporate to dryness, whereby it is converted into a mixture of chloride of calcium and chloride of lime devoid of bleaching power; dissolve it in water, filter, concentrate the solution by evaporation, then add to it 1 part of chloride of potassium, and cool for crystallization. The salt which may thereby be separated from the chloride of calcium will afford 0·83 of pure chlorate of potash. By this process of Professor Liebig five sixths of the potash are saved, but much oxygen is wasted in the evaporation to dryness of the chloride of lime, and consequently much chloric acid is lost towards the production of the salt. Vée mixes the chloride of lime pap, before heating it, with the chloride of potassium, boils the mixture smartly, whereby much oxygen is undoubtedly thrown off, and then sets the liquor aside to crystallize. L. Gmelin suggests that saturation of the liquor with chlorine before boiling might be advantageous. Gay Lussac has suggested to make this valuable salt by precipitating a solution of chloride of lime with carbonate (or sulphate) of potash, saturating the liquor after filtration with chlorine gas, evaporating, and crystallizing.

Professor Juch's process is to pass chlorine gas into a mixture of 1 pound caustic lime and 1 pound carbonate of potash, with 8 pounds of water. The resulting chloride of potash readily separates in the filtered liquid by crystallization from the very soluble chloride of calcium. By this method potash is not wasted in the useless production of chloride of potassium.

CHLORATES, compounds of chloric acid with the salifiable bases. The only acid belonging to this class of any manufacturing importance is the following:

CHLORIC ACID; the acid constituent of the preceding salt; it consists of one equivalent prime of chlorine $= 35{\cdot}476, + 5$ of oxygen, $= 40{\cdot}065$; of which the sum 75·535 is the prime equivalent of the acid.

CHLORINE; the most energetic of the undecompounded bodies, or chemical elements as they are usually called, exists, under ordinary circumstances, as a greenish yellow gas, but, when exposed to a pressure of 4 atmospheres, it becomes a yellow transparent liquid. In the first state, its density compared to air, reckoned 1·000, is 2·47; in the second, its density compared to water, 1·000, is 1·33. No degree of cold hitherto tried, has liquefied the gas when dry. It is obtained by putting into a glass retort a mixture of 3 parts of common salt, with 2 parts of peroxyde of manganese, and pouring upon it 2 parts of sulphuric acid diluted with its own weight of water; or, more conveniently, by pouring moderately strong muriatic acid upon peroxyde of manganese in a retort; and in either case applying the gentle heat of a spirit lamp or a water bath, while the beak of the retort is plunged under brine upon the shelf of the pneumatic trough. The gas issues, and may be received in the usual way into inverted glass jars, or vials; but the first which comes over, being mixed with the air of the retort, must be rejected. It has a peculiar smell, and irritates the nostrils most violently when inhaled, as also the windpipe and lungs. It is eminently noxious to animal life, and, if breathed in its undiluted state, would prove instantly fatal. It supports the combustion of many bodies,

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and indeed spontaneously burns several without their being previously kindled. The resulting combinations are called chlorides, and act most important parts in many manufacturing processes.

Water absorbs, at the ordinary temperature of the atmosphere, about double its volume of chlorine, and acquires the colour, smell, and taste of the gas, as well as its power of destroying or bleaching vegetable colours. When this aqueous chlorine is cooled to 36° Fahr. dark yellow crystalline plates appear in it of the hydrate of chlorine, which are composed in 100 parts of 27·7 chlorine, and 72·3 water. If these crystals be heated to about 45° they liquefy, and the gas flies off.

Chlorine has a powerful affinity for hydrogen, not only combining with it rapidly in the gaseous, but seizing it in many of its liquid and solid combinations, as in volatile oils, which it inflames, and in yellow wax, cotton and flax, which it whitens. The compound of chlorine and hydrogen gases is muriatic acid gas. Manganese, when mixed with liquid muriatic acid, as in the above process, abstracts the hydrogen, and lets the chlorine gas go free. When chlorine is passed into water, it decomposes some of it, seizes its hydrogen to form a little muriatic acid, and enables its oxygen to unite either with the chlorine, into chlorous acid, or with the remaining water, and to constitute oxygenated water. Hence, aqueous chlorine, exposed to the sunbeam, continually evolves oxygen, and, ere long, becomes muriatic acid.

This watery compound acts in a powerful way upon coloured vegetable fibres, extracting their hydrogen or colouring element by the twofold affinities of the chlorine and oxygen for it.

Hence chlorine as a bleaching agent, requires to be tempered by the quiescent affinity of some alkaline base, potash or lime. Malaria, or morbific and putrescent miasmata, consists chiefly of hydrogenous matter as their basis, and are best counteracted by chlorine, where it can be conveniently applied.

Chlorides of Potash, Soda, and Lime.—These are the most important preparations through which chlorine exercises its peculiar powers upon the objects of manufactures. When a weak solution of caustic potash or soda is saturated with chlorine, it affords a bleaching liquor which is still used by some bleachers and calico-printers for their most delicate processes; but the price of the alkalis has led to the disuse of these chlorides as a general means. and has occasioned an extensive employment of chloride of lime. Upon the manufacture of this interesting compound I made an elaborate series of experiments, several years ago, and published the results in the 13th volume of Brande's Journal for April, 1822. I have no reason to suppose, from any thing that has been published since, that the processes there described have been essentially improved, or that any errors, either theoretical or practical, of any moment, exist in that memoir. I shall therefore first present my readers with a brief abstract of it, and then make such observations as subsequent inquiries suggest.

In the researches which I made, at many different times, upon the nature of the chloride of lime, I generally sought to combine the information flowing from both synthesis and analysis; that is, I first converted a known portion of hydrate of lime into bleaching-powder, and then subjected this chloride to analysis.

Two hundred grains of the atomic proto-hydrate of pure lime were put into a glass globe, which was kept cold by immersion in a body of water at 50°. A stream of chlorine, after being washed in water of the same temperature in another glass globe, connected to the former by a long narrow glass tube, was passed over the calcareous hydrate. The globe with the lime was detached from the rest of the apparatus from time to time, that the process might be suspended as soon as the augmentation of weight ceased. This happened when the 200 grains of hydrate, containing 151·9 of lime, had absorbed 130 grains of chlorine. By one analytical experiment, it was found that dilute muriatic acid expelled from 50 grains of the chloride, 20 grains of chlorine, or 40 per cent.; and by another, from 40 grains, 16·25 of gas, which is 40·6 per cent.. From the residuum of the first 39·7 grains of carbonate of lime were obtained by carbonate of ammonia; from that of the second, 36·6 of ignited muriate of lime. The whole results are therefore as follows:—

	Synthesis.	1st Analysis.	2d Analysis.	Mean
Chlorine - -	39·39	40·00	40·62	40·31
Lime - - - -	46·00	44·74	46·07	45·40
Water - - -	14·60	15·26	13·31	14·28
	100 00	100·00	100·00	100·00

Though the heat generated by the action of the dilute acid had carried off in the analytical experiments a small portion of moisture with the chlorine, yet their accordance with the synthetic experiment is sufficiently good to confirm the general results. The above powder appears to have been a pure chloride, without any mixture of muriate. But it exhibits no atomic constitution in its proportions.

To 200 grains of that hydrate of lime 30 grains of water being added, the powder was subjected to a stream of chlorine in the above way, till saturation took place. Its increase of weight was 150 grains.

It ought to be remarked, that in this and the preceding experiment, there was no appreciable pneumatic pressure employed to aid the condensation of chlorine. In the last case, we see that the addition of 30 grains of water has enabled the lime to absorb 20 grains more of chlorine, being altogether a quantity of gas nearly equal to that of the dry lime. Thus, an atom of lime seems associated with seven ninths of an atom of chlorine. Analysis by muriatic acid confirmed this composition. It gave

Chlorine	-	39·5 = 51·8 cubic inches.
Lime	-	39·9
Water	-	20·6
		100·0

A great variety of apparatus has been at different times contrived for favouring the combination of chlorine with the slaked lime for the purposes of commerce. One of the most ingenious forms is that of a cylinder, or barrel, furnished with narrow wooden shelves within, and suspended on a hollow axis, by which the chlorine was admitted, and round which the barrel was made to revolve. By this mode of agitation, the lime-dust, being exposed on the most extensive surface, was speedily impregnated with the gas, to the requisite degree. Such a mechanism I saw at MM. Oberkampf and Widmer's celebrated *fabrique de toiles peintes*, at Jouy, in 1816. But this is a costly refinement, inadmissible on the largest scale of British manufacture. The simplest, and, in my opinion, the best construction for subjecting lime-powder to chlorine, is a large chamber 8 or 9 feet high, built of silicious sandstone, having the joints of the masonry secured with a cement composed of pitch, resin, and dry gypsum in equal parts. A door is fitted into it at one end, which can be made air-tight by strips of cloth and clay-lute. A window on each side enables the operator to judge how the impregnation goes on by the color of the air, and also gives light for making the arrangements within at the commencement of the process. As water lutes are incomparably superior to all others, where the pneumatic pressure is small, I would recommend a large valve or door on this principle to be made in the roof, and two tunnels of considerable width at the bottom of each side wall. The three covers could be simultaneously lifted off by cords passing over a pulley, without the necessity of the workman approaching the deleterious gas, when the apartment is to be opened. A great number of wooden shelves, or rather trays, 8 or 10 feet long, 2 feet broad, and 1 inch deep, are provided to receive the riddled slaked lime, containing generally about 2 atoms of lime to 3 of water. These shelves are piled one over another in the chamber, to the height of 5 or 6 feet, cross bars below each keeping them about an inch asunder, that the gas may have free room to circulate over the surface of the calcareous hydrate.

The alembics for generating the chlorine, which are usually nearly spherical, are in some cases made entirely of lead, in others of two hemispheres, joined together in the middle, the upper hemisphere being lead, the under one cast-iron. The first kind of alembic is enclosed, for two thirds from its bottom, in a leaden or iron case, the interval of two inches between the two being destined to receive steam from an adjoining boiler. Those which consist below of cast-iron have their bottom directly exposed to a very gentle fire; round the outer edge of the iron hemisphere a groove is cast, into which the under edge of the leaden hemisphere fits, the joint being rendered air-tight by Roman or patent cement. In this leaden dome there are four apertures, each secured by a water-lute. The first opening is about 10 or 12 inches square, and is shut with a leaden valve, with incurvated edges, that fit into the water channel at the margin of the hole. It is destined for the admission of a workman to rectify any derangement in the apparatus of rotation, or to detach hard concretions of salt from the bottom.

The second aperture is in the centre of the top. Here a tube of lead is fixed, which descends nearly to the bottom, and down through which the vertical axis passes. To its lower end the cross bars of iron, or of wood, sheathed with lead, are attached, by whose revolution the materials receive the proper agitation for mixing the dense manganese with the sulphuric acid and salt. The motion is communicated either by the hand of a workman applied from time to time to a winch at top, or it is given by connecting the axis with wheel work, impelled by a stream of water or a steam-engine. The third

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opening admits the syphon-formed funnel, through which the sulphuric acid is introduced; and the fourth is the orifice of the eduction-pipe.

Manufacturers differ much from each other in the proportion of their materials for generating chlorine. In general, 10 cwt. of salt are mixed with from 10 to 14 cwt. of manganese, to which mixture, after its introduction into the alembic, from 12 to 14 cwt. of sulphuric acid are added in successive portions. That quantity of oil of vitriol must, however, be previously diluted with water, till its specific gravity becomes about 1·6. But, indeed, this dilution is seldom actually made, for the manufacturer of bleaching-powder almost always prepares his own sulphuric acid for the purpose, and therefore carries its concentration no higher in the leaden boilers than the density of 1·65, which from my table of sulphuric acid, indicates $\frac{1}{4}$ of its weight of water, and therefore $\frac{1}{3}$ more of such acid must be used.

The fourth aperture, I have said, admits the eduction pipe. This pipe is afterwards conveyed into a leaden chest or cylinder, in which all the other eduction pipes also terminate. They are connected with it simply by water-lutes, having a hydrostatic pressure of 2 or 3 inches. In this general *diversorium* the chlorine is washed from adhering muriatic acid, by passing through a little water, in which each tube is immersed, and from this the gas is let off by a pretty large leaden tube, into the combination room. It usually enters in the top of the ceiling, whence it diffuses its heavy gas equally round.

Four days are required, at the ordinary rate of working, for making good marketable bleaching-powder. A more rapid formation would merely endanger an elevation of temperature, productive of muriate of lime, at the expense of the bleaching quality. But skilful manufacturers use here an alternating process. They pile up, first of all, the wooden trays only in alternate shelves in each column. At the end of two days the distillation is intermitted, and the chamber is laid open. After two hours the workman enters, to introduce the alternate trays covered with fresh hydrate of lime, and at the same time rakes up thoroughly the half-formed chloride in the others. The door is then secured, and the chamber, after being filled for two days more with chlorine, is again opened, to allow the first set of trays to be removed, and to be replaced by others, containing fresh hydrate, as before. Thus the process is conducted in regular alternation: thus, to my knowledge, very superior bleaching-powder is manufactured, and thus the chlorine may be suffered to enter in a pretty uniform stream. But for this judicious plan, as the hydrate advances in impregnation, its faculty of absorption becoming diminished, it would be requisite to diminish proportionately the evolution of chlorine, or to allow the excess to escape, to the great loss of the proprietor, and, what is of more consequence, to the great detriment of the health of the workmen.

The manufacturer generally reckons on obtaining from one ton of rock-salt, employed as above, a ton and a half of good bleaching-powder. But the following analysis of the operation will show that he ought to obtain two tons.

When a mixture of sulphuric acid, common salt, and black oxyde of manganese are the ingredients used, as by the manufacturer of bleaching-powder, the absolute proportions are, upon the oxygen scale of equivalents:—

1 atom muriate of soda - -	7·5	29·70	100·0
1 atom peroxyde of manganese -	5·5	21·78	73·3
2 atoms oil of vitriol 1·846 - -	12·25	48·52	163·3
	25.25	100.00	

And the products ought to be;—

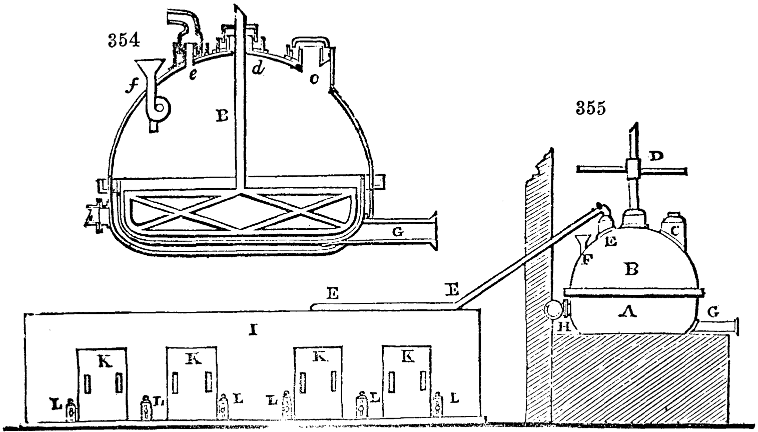
Chlorine disengaged - -	1 atom.	4·5	17·82
Sulphate of soda - -	1 —	9·0	35·64
Proto-sulphate of manganese -	1 —	9·5	37·62
Water - - -	2 —	2·25	8·92
		25·25	100·00

These proportions are, however, very different from those employed by many, nay, I believe by all manufacturers; and they ought to be so, on account of the impurity of their oxyde of manganese. Yet making allowance for this, I am afraid that many of them commit great errors in the relative quantities of their materials.

From the preceding computation, it is evident that 1 ton of salt with 1 ton of the above native oxyde of manganese properly treated, would yield 0·59 of a ton of chlorine, which would impregnate 1·41 tons of slaked lime, producing 2 tons of bleaching-powder, stronger than the average of the commercial specimens; or allowing for a little loss, which is unavoidable, would afford 2 tons of ordinary powder, with a little more slaked lime.

Fig. 354 represents a retort of lead, well adapted to the evolution of chlorine from the mixture of salt, manganese, and sulphuric acid, or from manganese and muriatic acid.

The interior vessel is cast in lead, and it has round its bottom part a cast-iron steam case. The salt and manganese are introduced by the aperture C, and the sulphuric acid by the syphon funnel F. The contact of these three substances is continually renewed by the agitator or stirrer B, which consists of wrought or cast iron sheathed with lead. *e* is the gas discharge pipe. The residuums are drawn off by the bottom discharge pipe G. The heating case receives its steam by the pipe *h*.



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355

The chlorine gas, *fig.* 355. is conveyed from the retort B, into the chamber I, by the tube E E E. This chamber is divided into four compartments, to receive the gas disengaged from four retorts, like the above. The bottom of it is covered with a stratum three or four inches thick of quicklime, newly slaked and sifted, which is stirred about from time to time, by the rakes L L L L. When the saturation is sufficient, the chloride of lime is taken out by the doors K K K K. The size of this apparatus allows 2 cwt. of manganese, and its equivalent quantity of salt and sulphuric acid, or of muriatic acid, to be introduced at once into the retort. D is the handle of the agitator.

The same form of retort will suit perfectly well to prepare chlorine for making liquid chloride of lime, which is preferred by many bleachers and calico-printers who have conveniences for preparing it themselves. The most concentrated solutions of the dry chloride of lime do not mark more than 6° B. (sp. grav. 1·04), and discolour only 50 volumes of Gay Lussac's solution of indigo, whilst the chloride made in the humid way marks from 8° to 9° B. (about 1·060), and discolours 80 volumes of the same solution.

In the chloride of lime apparatus, most generally used by the skilful calico-printers of Mülhausen, the mixture of muriatic acid and manganese is put into glass globes, with long necks, heated upon a sand-bath. The chlorine is conveyed by glass tubes into a cylindrical stone cistern, containing milk of lime. The furnace of the sand-baths is made of cast iron, and has brick partitions, to give each retort its own fire. The smoke of all these fires goes off by a flue into sheet iron pipes. The cistern is made of siliceous sandstone. Its cover is of wood, coated with a resinous cement; and it fits at its edges into grooves cut in the stone. A wheel serves to agitate the liquid continually; its paddles being kept at two inches distance from the sides of the cistern. The milk of lime is introduced by a funnel, and the chloride is drawn off by a discharge pipe. I think the lead retort and agitator used in this country greatly preferable to the experimental laboratory plan described above. In all such apparatus we should avoid giving any pressure to the tubes or vessels, and should not therefore dip the extremities of the gas pipes beneath the surface of the liquid, but rather facilitate the combination of the chlorine and the lime, by enlarging the surfaces of contact and by agitating. Intermediate vessels containing water, or the chemical cascade of M. Clement, are very useful for absorbing any muriatic acid which may be disengaged along with the chlorine, and thereby preventing the needless formation of muriate of lime in the chambers or cisterns of impregnation.

When the solution of the chlorine of lime is mixed with hydrate of lime, it bears, without decomposing, a pretty high temperature, provided it be not too long continued; it may even, in certain cases, be raised too near the boiling point without suffering a marked loss of its discolouring power; but when the chloride is deprived of that excess of lime, it is decomposed in a short time, even at a heat of 110° F.

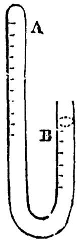
When chlorine is admitted to milk of lime, it infallibly produces some muriate of lime; but the quantity is kept at a *minimum* by constantly prescribing an excess of lime to the gas with the agitator, and by keeping the temperature as low as possible. Hence the influx of gas should not be so rapid as to generate much heat. An automatic agitator, moved by steam or water power, is therefore much better than one driven by the hand of the operator, who is apt to intermit his labours. If the liquor becomes hot at the end of the process, it should be immediately drawn off into large stone bottles, and cooled. The rose-colour which sometimes supervenes is due to a minute quantity of manganese. The strongest liquid chloride of lime that can be prepared will not discolour more than 80 times its volume of Gay Lussac's indigo test.

On acting upon cotton cloth with a concentrated solution of chloride of lime, at from 110° to 120° F., pure carbonic acid gas is disengaged, and the texture of the cloth is injured. Here the hydrogen of the water and the cotton being seized by the chlorine, the liberated oxygen combines with the carbon to form carbonic acid. In the discharge troughs, where printed calicoes are passed through strong solutions of chloride of lime, stalactitic crusts of carbonate of lime come to be formed in this way.

The *chlorometre* of Gay Lussac consists of a test solution of indigo and a graduated tube. One part of the best indigo, passed through a silk sieve, is to be dissolved in nine parts of concentrated sulphuric acid, by the aid of a water-bath heat applied for six hours. The sulphate of indigo is now to be diffused through such a body of water that one volume of chlorine gas shall discolour exactly ten times its volume of this dilute solution. The test liquor should be protected from the agency of light.

Mr. Crum, of Thorniebank, near Glasgow, has lately modified Dr. Dalton's copperas test for chloride of lime, and made it convenient to a practical man. The doctor justly considered that the more chlorine any bleaching powder contains, the more of the green sulphate of iron will it convert into the red sulphate, so that we have only to add successive portions of the chloride to a given weight of the dissolved copperas, and note the point at which all the iron gets peroxidized. See Bleaching.

Besides the method of analysis already quoted from my memoir on the manufacture of the chloride of lime, another occurred to me long ago, which I often practised as an easy and expeditious test. Chlorine decomposes ammonia. If therefore water of ammonia, faintly tinged with litmus, be added slowly to a solution of a given weight of chloride of lime, the colour will continue to disappear till the chlorine be all neutralized by the reaction of the hydrogen of the ammonia. The quantity of liquid ammonia of a certain strength requisite to neutralize, in this way, a certain volume, say, one cubic inch, or a thousand grain measures, of chlorine gas, may be assumed as the standard of such a chlorometer. As chlorine or chloride of lime, when mixed with water of ammonia, causes the disengagement of azote, the quantity of this gas evolved may also be made the foundation of an accurate and convenient chlorometer. The two substances should be mixed over mercury, in a graduated syphon tube. The shut end A and the open end B are both graduated to one scale; for example, to hundredths of a cubic inch, or to grain or 10 grain measures. The tube is to be filled with mercury, and then 10 measures of it are to be displaced at the open end by inserting a wooden plug. This space being filled with the solution of chloride of lime, is to be turned up into the shut end by covering the open end with the finger, and inverting the tube; a few drops of water may be sent through to wash the mercury. The ammonia being now let up will cause a reaction, and evolve a quantity of azote, equivalent to the chlorine present. The action may be quickened by holding the sealed end of the tube obliquely over a lamp heat. The mercury is protected from the chlorine by the ammonia; and should any notion be entertained of such an action, the ammonia may be let up first. I have made innumerable researches over mercury with a detached apparatus of that kind, which combines precision with rapidity of result. It was by a similar mercurial syphon that I analysed the carbonates, as described in the first edition of my Dictionary of Chemistry, 32 years ago.



M. Gay Lussac takes, as the basis of his indigo chlorometer, the fact, that one pound of pure crystallized peroxide of manganese is capable of affording, with muriatic acid, 0·7964 parts of a pound of chlorine; or one kilogramme yields 251¼ litres; that is, one pound yields 251¼ pound measures. Hence 3·98 grammes of that manganese are capable of affording 1000 gramme measures, or 1 litre of chlorine; or, in round numbers, 4 grains will yield 1000 grain measures. This quantity of gas being received into that volume of milk of lime, constitutes therefore Gay Lussac's primary standard. The small retort in which the manganese and muriatic acid are put ought to be heated to ebullition, to discharge every particle of chlorine. To prevent the manganese, in this experiment, from sticking to the bottom in a cake, it has been proposed to mix it previously with a little plumbago. See Chlorometry.

For preparing the chlorides of potash and soda, the same apparatus may be employed as for the liquid chloride of lime. The alkaline solutions should be weak, containing not more than a pound to the gallon of water. Potash liquor, saturated with chlorine, is much employed at Paris for whitening linen, under the name of the water of Javelle, the place where it was first made as a manufacture. One hundred parts of chlorine are said to saturate 133 parts of pure potash, and 195 of the carbonate: but the latter should not be used for preparing the bleaching fluid, as the carbonic acid resists the combination of the chlorine. A chloride of carbonate of soda has been lately recommended as a disinfecting substance against contagious miasmata or *fomites*. One hundred parts of chlorine will saturate 150 of the dry carbonate, and 405 of the crystallized. M. Payen prepares this medicinal chloride, by adding 138 parts of carbonate of soda to a liquid, consisting of water 1800, chloride of lime 100, at 98° of strength, by Gay Lussac's standard. The chloride of lime is to be dissolved, and the sediment well washed; the carbonate of soda, dissolved by heat, is to be poured into the solution, the precipitate allowed to subside, the clear fluid decanted, and the solid matter washed upon a filter. The collected solutions are neutral chloride of soda. Sixty-two parts of the carbonate of soda are then to be dissolved in the remainder of the water, and added to the preparation; the whole being thus filtered, a limpid liquid is obtained, indicating 5° by the hydrometer of Baumé.

The chloride of magnesia was long ago proposed by Sir H. Davy for bleaching linen, as being preferable to chloride of lime, because the resulting muriate of magnesia was not injurious to the fibre of cloth, as muriate of lime may be, under certain circumstances. I prepared a quantity of chloride of magnesia, by exposing a hydrate of that earth in the chlorine chamber of a large manufactory of chloride of lime at Glasgow, and obtained a compound possessed of considerable discolouring powers; but I found that the chlorine was so feebly saturated by the base, that it destroyed the colours of fast-dyed calicoes as readily as chlorine gas or chlorine water did, and was therefore dangerous for common bleaching, and destructive in clearing the grounds of printed goods, which is one of the most valuable applications of the calcareous and alkaline chlorides. The occasion of my making these experiments was the importation of a considerable quantity of magnesite, or native atomic carbonate of magnesia, from the district of Madras, by an enterprising friend of mine. Encouraged by the encomiums bestowed on the chloride of magnesia by many chemical writers, he expected to have benefited both the country and himself, by bringing home the earthy base of that compound, at a moderate price; but was disappointed to his cost.

Dr. Thomson is of opinion that the bleaching compound of lime and chlorine is not a chloride of lime, but a combination of chlorous acid with lime and of chlorine with calcium: consisting in its most concentrated state of

3 atoms of chloride of calcium = 21
1 atom of chlorite of lime - = 11
—
32
—

So that about one-third of the weight is chlorite of lime, to which alone the bleaching powers of the substance are owing. He admits a fact, rather inconsistent with this opinion, that bleaching powder does not attract moisture from the atmosphere with nearly so much rapidity as might be expected from a mixture containing two-thirds of its weight of so deliquescent a salt as muriate of lime; unless this indeed be prevented by the chloride and chlorite being united into a double salt, which is a mere conjecture without either proof or analogy. And further, when dilute sulphuric or muriatic acid is poured upon bleaching powder, a profusion of chlorine is given out immediately, which he also admits to be inconsistent with the notion of its being a mixture of chloride of calcium and chlorite of lime, for no such evolution takes place when the above acids are mixed with solutions of chloride of calcium and chlorate of potash. Though I am of opinion that bleaching powder is simply a chloride of lime, in which the lime corresponds to the water in the aqueous chlorine, yet I cannot see the truth or appositeness of his last reason, because chlorine is certainly given out when chlorate of potash is acted upon by dilute muriatic acid, as any man may prove by adding to a mixture of these two substances a vegetable colour; for it will be speedily blanched. Dr. Thomson considers the chloride which is at present made in Mr. Tennant's great factory, as containing one atom of chlorine associated with one atom of lime, or, taking his numbers, as consisting of

Hydrate of lime 4·625
Chlorine - 4·5

or nearly equal weights of the chlorine and the base; indicating a surprising degree of excellence in the preparation. The average commercial samples of bleaching powder from different factories which I examined some years ago, did not possess nearly that strength; but varied in their quantity of chlorine from 20 to 28 per cent. In my synthetic experiments related above, the greatest quantity of chlorine that would combine with the atomic hydrate of lime was in the proportion of 130 to 200; but there is no doubt that, if the lime contains additional water, it will condense more gas. I have never seen a chloride of lime of the strength mentioned by Dr. Thomson, and I should think there must be some fallacy in his statements. I have recorded in the paper above quoted an experiment which proves that, with additional moisture, a chloride of lime may be obtained of the following composition:—

Chlorine	39·5
Lime -	39·9
Water -	20·6
	100·0

In the article Bleaching, of the Encyclopædia Britannica, Dr. Thomson deduces, from a test trial of Mr. Crum, that the best bleaching powder is a compound of 1 atom chlorite of lime = 11, 3 atoms chloride of calcium = 21, and 3 atoms of water = 9. "But," adds he, "in general the whole lime is not accurately saturated with chlorine. Accordingly, when the bleaching powder is dissolved in water a small residue almost always remains undissolved. Unless the powder be fresh made, a portion of chlorite is always converted into chloride of calcium. It is probable, therefore, that the best bleaching powder, as it comes into the hands of the bleachers, consists of

1 atom chlorite of lime -	11
3 atoms chloride of calcium	21
6 atoms water - - - -	6·75
Impurity - - - -	2·25
	41·00

'If we consider the bleaching powder as a compound of chlorine and lime, our mode of calculating will not be altered. Instead of 1 atom chlorite of lime, and 3 atoms chloride of calcium, we shall have 4 atoms chloride of lime, 6 atoms water, and 2·25 of impurity as before." In such ambiguity does this able chemist place this interesting compound, for theoretical reasons, of which I cannot see the value. Surely there is no difficulty in conceiving chlorine to exercise a direct attractive force towards the hydrate of lime, as it is known to do towards each of its elementary constituents, the oxygen and the calcium. Such refinements as the preceding tend merely to mystify a plain matter. Even the chlorous acid here brought into play to form the ideal chlorite, is by his own admission a hypothetical being. "When chlorate of potash," says Dr. Thomson, "is mixed with sulphuric acid, and made into small balls the size of a pea, if we expose these balls to a heat somewhat lower than that of boiling water, a bright yellowish green gas separates, which may be received over mercury. Its smell is peculiar and aromatic. Water absorbs at least seven times its volume of it. It destroys vegetable blues. Its constituents are,

1 volume chlorine	2·5	or 4·5
2 volumes oxygen	2·222	or 4.

Thus this compound consists in weight of chlorine 4·5, oxygen 4 = 8·5. It has been called *quateroxide of chlorine*, but it is more probably a *teroxide*. It has been supposed by some to possess acid properties, and has therefore been called *chlorous acid*. But this is only as yet a hypothesis.

Surely this, by the doctor's own showing, is very slender authority for renouncing our long-received doctrines concerning the constitution of bleaching powder. I shall conclude by remarking that the ultra-atomists are now in a dilemma about this substance; M. Welter, and many French chemists, calling it a sub-chloride of 1 atom of chlorine to 2 atoms of lime, and Dr. Thomson showing that Mr. Tennant, the greatest and best manufacturer of it, has produced it in the state of a chloride, or 1 atom of each. The fact is, in chloride of lime, as in water of ammonia, alcohol, and muriatic acid, there is no *sufficient reason* for definite proportion in any term short of saturation, and therefore we shall find *that* chloride in every gradation of strength from 1 per cent. of chlorine up to 40 per cent.—the strongest which I succeeded in preparing, though I passed a constant stream of chlorine in great excess over a pure hydrate of lime for upwards of 24 hours, with frequent renewal of the surface; indeed, till it refused to absorb any more gas, as indicated by its remaining stationary in weight.

CHLORINE AND ALKALI (*Manufacture of*). Mr. Tennant Dunlop of Glasgow obtained, in March, 1847, a patent for an improved method of producing chlorine. The process he usually adopts is to bring together common salt, nitrate of soda, or nitric acid and sulphuric acid, in suitable proportions; heat being then applied, chlorine or an oxide of azote and muriatic acid are evolved; these gases are caused to pass through a condenser charged with sulphuric acid of sufficient strength to absorb the oxide of azote; and then the chlorine and muriatic acid are separated by means of water.

In applying the product resulting from the above process, he obtains nitric acid from the sulphuric acid charged with oxide of azote, which is true nitrous sulphuric acid. This is effected by the aid of atmospheric air, steam, and water. He introduces the nitrous sulphuric acid into a suitable vessel, and by the addition of water and heat, he effects the disengagement of oxide of azote, which being caused to traverse a condenser with a sufficient quantity of air and steam or water, is by this means transformed into nitric acid. This acid may be again used in the manufacture of chlorine, and again recovered, and so on. Sometimes, instead of treating the nitrous sulphuric acid as just described, the patentee causes the oxide of azote to be evolved, and to pass into a chamber into which a current of sulphuretted hydrogen is streaming; by which means sulphate of ammonia is obtained and sulphur deposited.

CHLOROMETRY; *Chlorometrie*, is the name given by the French to the process for testing the decoloring power of any combination of chlorine, but especially of the commercial articles, the chlorides of lime, potash, and soda. M. Gay Lussac proposed many years ago the following *graduated* method of applying indigo to this purpose. As indigo varies much in its dyeing quality, and of consequence in the proportion of chlorine required for its decoloration, he assumes as the unity of blanching power, one litre of chlorine gas, measured at the mean pressure of 29·6 inches, and at the temperature of melting ice. This volume of gas, when combined with a determinate quantity of water, is employed to test the standard solution of indigo. For this purpose a solution in sulphuric acid of any sample of indigo is taken, and diluted with water to such a degree that 10 measures of it, in a graduated tube, are decolored by that one measure of combined chlorine gas. Each measure of indigo solution so destroyed is called a degree, and this measure being divided into five parts, the real test of chlorine is given to fiftieths, which is sufficiently nice. For the standard of the assays, a chloride of lime as pure and fully saturated as possible is taken, and dissolved in such a quantity of water, that the solution shall contain, or be equivalent to, one volume of chlorine gas. Calculation proves that this condition is exactly fulfilled by dissolving 4938 grammes of the said chloride in half a litre of water; or in English measures, 5 gr. very nearly in 500 grain measures of water. This solution, which serves for a type, indicates 10° in the assay, or proof; that is to say, each single volume destroys the color of 10 volumes of the dilute indigo solution. It may be remarked that a greater degree of precision is in general attainable with a weak solution of chlorine or a chloride, for example at 4° or 5°, than with one much stronger; consequently if, after a preliminary trial, the standard considerably exceeds 10°, a given volume of water must be added to the solution, and then the above proof must be taken. If the volume of water added was double, the number of degrees afterward found must be tripled, to obtain the true title of the chloride. It is, however, to be observed that the degree of decoloration varies with the time taken in making the mixture; the more slowly the chlorine is added to the indigo, the less of it escapes into the atmosphere, and the more effective it becomes in destroying the color. The best mode of obtaining comparable results, is to pour suddenly into the test quantity of chlorine the whole volume of the indigo solution likely to be decolored; but it is requisite to find approximately beforehand, what quantity of indigo-blue will probably be destroyed. When it comes to the verge of destruction, it is green; but yellowish-brown when entirely decomposed.

I have tried the indigo test in many ways, but never could confide in it. The sulphuric solution of indigo is very liable to change by keeping, and thus to lead to erroneous results. The method of testing the chlorides by green sulphate of iron, described under bleaching, is in my opinion preferable to the above.

M. Gay Lussac has recently proposed another proof of chlorine, founded on the same principle as that by green vitriol, namely, the quantity of it requisite to raise a metallic substance from a lower to a higher stage of oxydizement. He now prescribes as the preferable plan of chlorometry, to pour very slowly from a graduated glass tube, a standard solution of the chloride, to be tested upon a determinate quantity of arsenious acid dissolved in muriatic acid, till the whole arsenious be converted into the arsenic acid. The value of the chloride is greater the less of it is required to produce this effect. It is easy to recognise, by a few drops of solution of indigo, the instant when all the arsenious acid has disappeared; for then the blue tint is immediately effaced, and cannot be restored by the addition of a fresh drop of indigo solution.

In graduating the arsenical chlorometer, M. Gay Lussac takes for his unity the decolouring power of one volume of chlorine of 32° Fahr., and divides it into 100 parts. Suppose that we prepare a solution of chlorine containing its own volume of the gas, and an arsenious solution, such that, under a like volume, the two solutions shall reciprocally destroy each other. Let us call the first, the normal solution of chlorine, and the second, the normal arsenious solution. We shall fix at 10 grammes the weight of chloride of lime subjected to trial; and dissolve it in water, so that the total volume of the solution shall be a litre (1000 grammes measure,) including the sediment. If we take a constant volume of this solution, 10 centimetres cube (10 gramme measures,) for example, divided into 100 equal parts, and pour into it gradually the arsenious solution (measured by like portions), till the chlorine be destroyed, the bleaching power will be proportional to the number of portions of the arsenious solution, which the chloride shall have required. If the chloride has destroyed 100 portions of the arsenious solution. its title will be 100; if it has destroyed 80 portions, its title will be 80, &c., and so forth.

On pouring the acidulous arsenious solution into the chloride of lime, this will become very acid; the chlorine will be emitted abundantly, and the proof will be quite incorrect. If, on the contrary, we pour the solution of the chloride of lime into the arsenious solution, this evil will not occur, since the chlorine will always find plenty of arsenious acid to act upon, whatever be the dilution of the one or the other; but in this case, the standard of the chlorine is not given directly, as it is in the inverse ratio of the number of portions which are required to destroy the measures of the arsenious solution. If 50 portions of the chloride have been required, the proof will be $100 \times \frac{100}{50} = 200°$; if 200 have been required, the proof will be $100 \times \frac{100}{200} = 50°$, &c. This evil is not, however, very serious, since we have merely to consult a table, in which we can find the proof corresponding to each volume of the chloride employed for destroying the constant measure of the arsenious solution. The arsenious solution should be slightly tinged with sulphate of indigo, so as to show, by the disappearance of the color, the precise point or instant of its saturation with chlorine, that is, its conversion into arsenic acid. If the arsenious acid be pure, the normal solution may be made directly by dissolving 4·439 grammes of it in muriatic acid (free from sulphurous acid), and diluting the solution till it occupies one litre, or 1000 grammes measure. *Annales de Chimie et Physique*, LX. 225.

CHOCOLATE is an alimentary preparation of very ancient use in Mexico, from which country it was introduced into Europe by the Spaniards in the year 1520, and by them long kept a secret from the rest of the world. Linnæus was so fond of it, that he gave the specific name, *theobroma*, food of the gods, to the cacao-tree which produced it. The cacao-beans lie in a fruit somewhat like a cucumber, about 5 inches long and 3½ thick, which contains from 20 to 30 beans, arranged in 5 regular rows with partitions between, and which are surrounded with a rose-colored spongy substance, like that of water-melons. There are fruits, however, so large as to contain from 40 to 50 beans. Those grown in the West India islands, Berbice and Demarara, are much smaller, and have only from 6 to 15; their development being less perfect than in South America. After the maturation of the fruit, when their green color has changed to a dark yellow, they are plucked, opened, their beans cleared of the marrowy substance, and spread out to dry in the air. Like almonds, they are covered with a thin skin or husk. In the West Indies they are immediately packed up for the market when they are dried; but in the Caraccas they are subjected to a species of slight fermentation, by putting them into tubs or chests, covering them with boards or stones, and turning them over every morning, to equalize the operation. They emit a good deal of moisture, lose the natural bitterness and acrimony of their taste by this process, as well as some of their weight. Instead of wooden tubs, pits or trenches dug in the ground are sometimes had recourse to for curing the beans; an operation called *earthing* (*terrer*). They are lastly exposed to the sun, and dried. The latter kind are reckoned the best; being larger, rougher, of a darker brown color, and, when roasted, throw off their husk readily, and split into several irregular fragments; they have an agreeable mild bitterish taste, without acrimony. The Guiana and West India sorts are smaller, flatter, smoother-skinned, lighter-colored, more sharp and bitter to the taste. They answer best for the extraction of the butter of cacao, but afford a less aromatic and agreeable chocolate. According to Lampadius, the kernels of the West India cacao beans contain, in 100 parts, besides water, 53·1 of fat or oil, 16·7 of an albuminous brown matter, which contains all the aroma of the bean, 10·91 of starch, 7¾ of gum or mucilage, 0·9 of lignine, and 2·01 of a reddish dye stuff somewhat akin to the pigment of cochineal. The husks form 12 per cent. of the weight of the beans; they contain no fat, but, besides lignine, or woody fibre, which constitutes half their weight, they yield a light brown mucilaginous extract by boiling in water. The fatty matter is of the consistence of tallow, white, of a mild agreeable taste, called butter of cacao, and not apt to turn rancid by keeping. It melts only at 122° Fahr., and should, therefore, make tolerable candles. It is soluble in boiling alcohol, but precipitates in the cold. It is obtained by exposing the beans to strong pressure in canvas bags, after they have been steamed or soaked in boiling water for some time. From 5 to 6 ounces of butter may be thus obtained from a pound of cacao. It has a reddish tinge when first expressed, but it becomes white by boiling with water.

The beans, being freed from all spoiled and mouldy portions, are to be gently roasted over a fire in an iron cylinder, with holes in its ends for allowing the vapours to escape; the apparatus being similar to a coffee-roaster. When the aroma begins to be well developed, the roasting is known to be finished; and the beans must be turned out, cooled, and freed by fanning and sifting from their husks. The kernels are then

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to be converted into a paste, either by trituration in a mortar heated to 130° F., or by the following ingenious and powerful machine. The chocolate paste has usually in France a little vanilla incorporated with it, and a considerable quantity of sugar. which varies from one-third of its weight to equal parts. For a pound and a half of cacao, one pod of vanilla is sufficient. Chocolate paste improves in its flavour by keeping, and should therefore be made in large quantities at a time. But the roasted beans soon lose their aroma, if exposed to the air.

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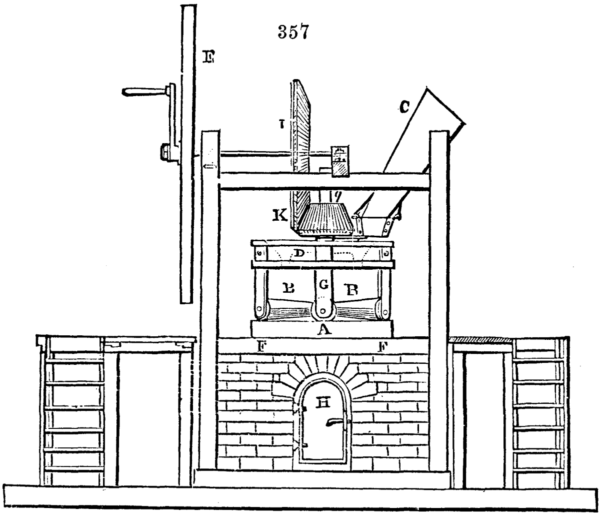

Fig. 357 represents the chocolate mill. Upon the sole A, made of marble, six conical rollers B B, are made to run by the revolution of the upright axis or shaft *q*, driven by the agency of the fly wheel E and bevel wheels I K. The sole A rests upon a strong iron plate, which is heated by a small stove, introduced at the door H. The wooden frame work F, forms a ledge, a few inches high, round the marble slab, to confine the cocoa in the act of trituration. C is the hopper of the mill through which the roasted beans are introduced to the action of the rollers, passing first into the flat vessel D, to be thence evenly distributed. After the cacao has received the first trituration, the paste is returned upon the slab, in order to be mixed with the proper quantity of sugar, and vanilla, previously sliced and ground up with a little hard sugar. When the chocolate is sufficiently worked, and while it is thin with the heat and trituration, it must be put carefully into the proper moulds. If introduced too warm, it will be apt to become damp and dull on the surface; and, if too cold, it will not take the proper form. It must be previously well kneaded with the hands, to ensure the expulsion of every air bubble.

In Barcelona, chocolate mills on this construction are very common, but they are turned by a horse-gin set to work in the under story, corresponding to H in the above figure. The shaft G is, in this case, extended down through the marble slab, and is surrounded at its centre with a hoop to prevent the paste coming into contact with it. Each of these horse-mills turns out about ten pounds of fine chocolate in the hour, from a slab two feet seven inches in diameter.

Chocolate is flavoured with cinnamon and cloves, in several countries, instead of the more expensive vanilla. In roasting the beans the heat should be at first very slow, to give time to the humidity to escape; a quick fire hardens the surface, and injures the process. In putting the paste into the tin plate, or other moulds, it must be well shaken down to insure its filling up all the cavities, and giving the sharp and polished impression so much admired by connoisseurs. Chocolate is sometimes adulterated with starch; in which case it will form a pasty consistenced mass when treated with boiling water. The harder the slab upon which the beans are triturated, the better; and thence porphyry is far preferable to marble. The grinding rollers of the mill should be made of iron, and kept very clean.

About eight years ago, samples of chocolate were sent to me for analysis, by order of the Lords of the Admiralty. It was made at the victualling-yard, Deptford, for the use of the Royal Navy, by the government chocolate mills, where about

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400 tons are annually prepared, to be distributed to the sailors and convicts at the rate of an ounce daily, and to be used at their breakfast. After taking the said chocolate for some time, men in several ships complained of its occasioning sickness, vomiting, purging, and more serious maladies, terminating in a few cases fatally. I examined it with great care, but could find no injurious ingredient in it, and no chemical alterations from the beans of the Guyaquil coco from which it was manufactured. But I observed that it consisted of gritty grains, from very imperfect trituration or milling; that these grains were quite immiscible with water, like so much fine gravel; that they contained many sharp spiculæ of the coco-bean husks, and that hence, when swallowed, they were calculated to form mechanically irritating lodgments in the villous coats of the stomach and bowels, whereby they could produce the morbid effects certified by several naval surgeons. It was, moreover, obvious that, from the insoluble condition of the chocolate, it could be of little use as an article of food, or as a demulcent substitute for milk, and that, in fact, three-fourths of it were, on this account, an ineffective article of diet, or were wasted.

Having reported these results and opinions to the Lords of the Admiralty, they were pleased after a few weeks' consideration, to request me to go down to the victualling-yard at Deptford, and superintend the preparation of a quantity of chocolate in the best manner I could with the means there provided. I accordingly repaired thither on the 13th September, 1842, and experienced the utmost courtesy and co-operation from Sir John Hill, the Captain Superintendent, and his subordinate officers. The coco-beans had been hitherto milled, after a slight roasting upon the sole of an oat-kiln, along with their husks. As I was satisfied, from analysis, that the husks were no better food than saw-dust, and that they might cause irritation by their minute spiculæ left after grinding between rotating millstones, I set about a plan for shelling them, but could find no piece of apparatus destined for the purpose. There was, however, a pea-shelling mill, which had been used only for one day some years before, and had stood ever since idle*, which, on being cleaned and having its millstones placed at a proper distance, was found to answer pretty well. The beans for experiment, to the amount of 6 cwt., had been previously roasted, under my care, at a well-regulated heat, with much stirring, in the oat-kiln; and, on being cold, were run through the shelling mill, which was put in communication with the fanners of the flour mill. By this arrangement, the coco-beans were tolerably shelled, and the kernels separated from their scaly husks. The weighings were accurately made.

6 cwt. of the Guyaquil coco - - -		672 lbs.
Lost in roasting - -	43	
shells - -	54	117
waste - -	20	
Remained for milling - -		555

On the 14th September I made a report to the Lords of the Admiralty upon the experiments of the 13th, of which the following is an outline. After describing the pains taken to regulate the roasting temperature, and to equalize the effect upon the beans by moving them occasionally by a rake, I stated that the oat-kiln was not well adapted to the purpose of roasting the coco, because it was impossible to turn the beans regularly and continuously during the process, so that they could not be equally roasted, and because it was an unwholesome operation for the workmen, who must go into a chamber filled with noxious gases and fumes, to use the rakes. When the door of the kiln was shut, to allow the burned air from the fire below to draw up through it, mischief might be done to the stratum of coco on the sole, and when the door was again opened, to permit a person to go in and stir, time and heat were wasted in replenishing the chamber with fresh air. I understood that a revolving-cylinder-roasting machine had been made by Messrs. Rennie for the chocolate process at Deptford; but, for reasons unknown to me, it had never been employed.

The diminution of weight by roasting and shelling may be estimated at about 17 per cent. A part of this loss is moisture, which should be completely expelled, to prevent its causing the chocolate to become mouldy at sea. But a part of the defalcation was also due to some of the coco remaining in the crevices of the pea-splitting mill and the fanners, which would not be observable if these were in constant employment. I think, therefore, that the roasted kernels may be estimated in general at 85 per cent. of the raw beans.

Fig. 358 represents the chocolate mills at the victualling-yard, Deptford, as mounted by the celebrated engineers, Messrs. Rennie. There are four double mill-stones A, B, C, D, each three feet in diameter, of which the nether rests upon a bed of cast iron, like a drum-head, kept at the temperature of about 220° by the admission of steam to the case below. Over each mill there is a feeding-hopper 1, 2, 3, 4, in communication by the pipes 5, 6, 7, 8, with the general reservoir E, charged upon the floor above with cocoa through the funnel placed over it. The vertical shafts which turn these mills are marked F, G, H, L; they are moved by the train of bevel-wheels above, which are driven by an arm from the main shaft of the steam engine. Each mill can, of course, be thrown in and out of geer at pleasure. At I, I, I, I, the discharge-spout is shown, which pours out the semi-fluid hot chocolate into shallow cylindrical tin pans, capable of containing about nine pounds of chocolate each. These four mills are capable of converting upwards of a ton of coco into good chocolate in a day, on the system of double trituration which I adopted, and two tons on the former rough plan. I found that the two stones of each mill had been placed so far asunder as would allow entire beans to pass through, as spurious chocolate, at one operation; but the chocolate thus discharged was in a very gritty state, whereas good chocolate in the liquefied state should

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* It was found that peas in their skin kept better at sea than the split peas, and they were also preferred by the sailors in their natural state.

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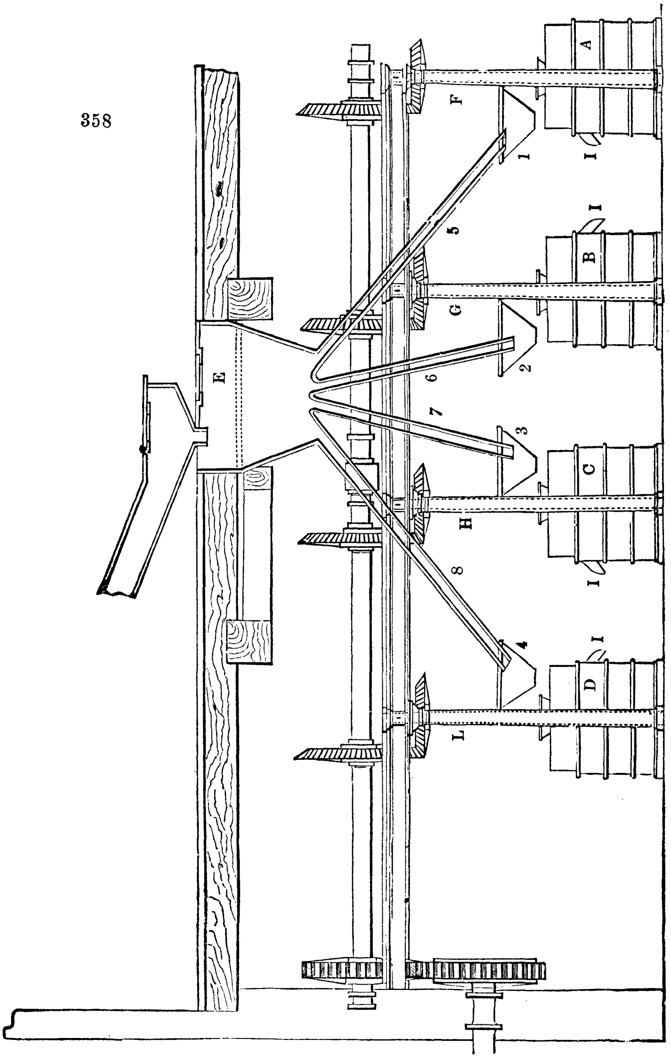

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be smooth and plastic between the fingers, and spread upon the tongue without leaving any granular particles in the mouth. To obtain such a result, I divided the milling into two steps; for the first, two pairs of the stones, A and C, were set as close together as for a paint mill (which they closely resemble), and the other two pairs, B and D, were left at their ordinary distance. The paste obtained from the first set was transferred, while nearly liquid, into the hoppers of the second pairs, from which it issued at the spouts as thin and smooth as honey from the comb. In subserviency to these experiments, I made an analysis of the Guyaquil coco, which I found to be composed as follows:—

Concrete fat or butter of coco, dissolved out by ether - - -	37
Brown extractive, extractible by hot water, after the operation of ether	10
Ligneous matter, with some albumine - - - - - -	30
Shells - - - - - - - - - -	14
Water - - - - - - - - - -	6
Loss - - - - - - - - -	3
	100

The solid fat of the coco should be most intimately combined by milling with the extractive albumine, and ligneous matter, in order to render it capable of forming an emulsion with water; and, indeed, on account of the large proportion of concrete fat in the beans some additional substance should be introduced to facilitate this emulsive union of the fat and water. Sugar, gum, and starch or flour are well adapted for this purpose.

Under this conviction, I employed in the first of these trials at Deptford, made with one-half of the above roasted kernels = 277½ lbs., 5 per cent. of sugar, which was first mixed upon a board with shovels, and the mixture was then put progressively into the hoppers of the two mills B and D. The paste which ran out of their spouts was immediately poured into the hoppers of A and C, from which it flowed smooth and very thin into the concreting pans. The sugar supplied to me was exceedingly moist, whereas it ought to be dry, like the bag sugar of the Mauritius. The other half of the coco kernels was milled alone once by the ordinary mills B and D. I subjected next day samples of these two varieties of chocolate to the following examination, and compared them with the sample of chocolate as usually made at Deptford, as also with a sample of chocolate sold by a respectable grocer in London. A like quantity of these four samples was treated with eight times its weight of boiling water, the diffusion well stirred, and then left to settle in a conical wineglass. Of the ordinary Deptford coco, four-fifths rapidly subsided in coarse grains, incapable of forming any thing like an emulsion with water, and therefore of little or no avail in making a breakfast beverage.

1. The single-milled chocolate made under my direction formed a smoother emulsion than the last, on account of the absence of the coco husks; but its particles were gritty, and subsided very soon.

2. The sugar double-milled chocolate, on the contrary, formed a milky-looking emulsion, which remained nearly uniform for some time, and then let fall a soft mucilaginous deposit, free from grittiness.

3. The shop chocolate formed a very indifferent emulsion, though it was well milled, because it contained evidently a large admixture of a coarse branny flour, as is too generally the case.

I have given small samples of the above No. 2. chocolate to various persons, and they have considered it superior to what is usually sold by our grocers. The presence of dry sugar in chocolate would also give it a conservative quality at sea, and prevent it from getting musty.

The Lords of the Admiralty, after seeing the above two samples of chocolate and my report thereupon, were, about six weeks afterwards, pleased to request me to make at their victualling-yard further experiments in the preparation of chocolate; and they indicated two modes, one of milling twice with the husks, and another of milling twice without the husks; permitting me, at the same time, to mill a portion of the kernels with 10 per cent. of sugar, and a second portion of the kernels with 5 per cent. of sugar and 5 per cent. of the excellent flour used in making the biscuits for the royal navy. On the 24th October, 1842, I accordingly performed these experiments upon 12 cwt. of Guyaquil coco as carefully roasted as possible on the kiln.

The loss in drying and slightly roasting the 1344 lbs. of beans was 5 per cent.

1st experiment, 212 lbs. of roasted coco, milled twice with the husks,
produced of chocolate - - - - - - - - 209 lbs
2d experiment, 191 lbs. ditto, milled twice without husks - - 189

3d experiment, 191 lbs. kernels, milled once along with 19 lbs. of sugar =210 lbs. - - - - - - - - 212*

4th experiment, 573 lbs. of kernels, milled twice along with 68 lbs. of flour and 34 of sugar = 675 - - - - - 669

Sample cakes of these four varieties of chocolate were subsequently sent to me for examination and report. I found that the chocolate milled twice with the flour and sugar formed a complete emulsion with hot water, bland and rich, like the best milk, but the other three were much inferior in this respect. Sugar alone, with proper milling, would serve to give the kernels of well roasted coco a perfect emulsive property. Instead of merely milling with rotary stones, I would prefer, for the second or finishing operation, a levigating mill, in which rollers would be rolled either backwards and forwards, or, when slightly conical, in a circular direction, over a plane metallic, marble, or porphyry, slab as is now, indeed, very generally practised by the trade. The coco-beans should be well selected, without musty taint, and possessed of a fine aroma, like the best of that imported from Trinidad. There is a great deal of very coarse coco and chocolate on sale in London and in the provincial towns of the United Kingdom.

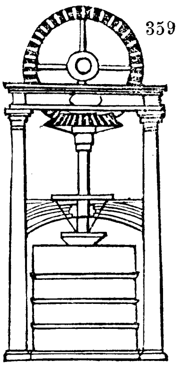
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Fig. 359. is an end view of one of the chocolate mills with its mitre-gearing. I consider the gritty chocolate hitherto made at Deptford as a very bad substitute for the chocolate which was made from coco by the sailors themselves with a pestle and mortar.

In 1840 the coco cleared for consumption in the United Kingdom was:—

British plantation - -	2,041,492 lbs.
Foreign - - -	186
Coco-nut husks and shells -	753,580
Chocolate and coco paste -	2,066

Of the cocoa-nut shells, 612,122 lbs. were consumed in Ireland! and less than 4000 lbs. of coco.

Of coco, 726,116 lbs. were consumed in her Majesty's navy.

How scurvily are the people of Ireland treated by their own grocers! Upwards of 600,000 lbs. of worthless coco husks served out to them along with only 4000 lbs. of coco-beans!

The quantity of coco imported in 1850 amounted to 4,478,252 cwts., and in 1851 to 6,773,960 cwts.; the entries for home consumption were 3,103,926 and 3,024,338 cwts.; the re-exports were 1,443,363 and 1,543,455 cwts.; and the gross amount of duty 16,059*l.* and 15,778*l.* respectively.

CHROMATES, saline compounds of chromic acid with the basis. See CHROMIUM.

Messrs. Swindell and Co. obtained a patent in November, 1850, for obtaining copper, silver, and chrome, from their ores.

1st. To obtain copper and silver, or copper only, from their ores, according to this invention, the ores are first roasted to drive off the sulphur, and convert the metals to the state of oxides, after which the prepared ores are placed in tanks, and a solution of ammonia or its salts, of a strength of about 0·980, pumped on in sufficient quantity to saturate them. This solution is removed at the expiration of twelve to twenty-four hours, and will be found saturated with the metallic oxides, which are to be dissolved in boiling water and precipitated—the silver by hydrochloric, and the copper by hydrosulphuric acids or otherwise.

2nd. The ore from which zinc is obtained is the native sulphuret, which is mixed with about its own weight of common salt (for which muriate of potash, or of any earth, may be substituted), and exposed in a calcining furnace to a slow protracted heat, until all the sulphur present is converted into sulphuric acid. The products of this operation will be sulphate of soda, muriate of zinc, and muriate of iron, which are to be dissolved out in boiling water, and the two latter precipitated by lime, or other means, after the sulphate of soda has been separated in the usual manner. The oxide of zinc, when thus precipitated, may be smelted in the usual way.

In treating chromium (chromite of iron), the ore is pulverized and mixed with common salt, muriate of potash, or hydrate of lime, and exposed in a reverberatory furnace to a red or even a white heat, the mixture being stirred every ten or fifteen minutes, and steam at a very elevated temperature introduced during the operation, until the desired effect is obtained, which may be ascertained by withdrawing a portion from the furnace and testing it, as customary. The products of this operation are finally treated in the manner usual for chromic and bichromic salts.

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* This small excess proceeded from a residue of the last experiment.

The mixture of chromium and common salt produces chromate of soda, the greater portion, or perhaps all of the iron contained in the chromium being absorbed by the hydrochloric acid evolved from the salt, and carried off in the form of sesquichloride of iron. From the first mixture is manufactured pure bichromate of soda, which, by the addition of hydrochloric acid, may be converted to chlorochromate; and from the last, or lime mixture, is produced a chromate of that earth, from which, by the addition of soda or potash, there may be obtained a compound salt, which, with those previously mentioned, may be advantageously employed in the operation specified in the title.

CHROMIC ACID. To a boiling saturated solution of bichromate of potash, add as much oil of vitrol as will convert the potash into a bisulphate. Let the whole cool, and be then washed with a little water, and stirred, when the liquid decanted from the granular mass will be nearly pure chromic acid.

The solution of chromic acid in oil of vitriol is preferable as an oxidizing agent to every other at present known. See Chromium.

CHROMIUM. The only ore of this metal, which occurs in sufficient abundance for the purposes of art, is the octohedral chrome-ore, commonly called chromate of iron, though it is rather a compound of the oxydes of chromium and iron. The fracture of this mineral is uneven; its lustre imperfect metallic; its color between iron-black and brownish-black, and its streak brown. Its specific gravity, in the purest state, rises to 4·5; but the usual chrome-ore found in the market varies from 3 to 4. According to Klaproth, this ore consists of oxyde of chromium, 43; protoxyde of iron, 34·7; alumina, 20·3; and silica, 2; but Vauquelin's analysis of another specimen gave as above, respectively, 55·5, 33, 6, and 2. It is infusible before the blowpipe; but it acts upon the magnetic needle, after having been exposed to the reducing smoky flame. It is entirely soluble in borax, at a high blowpipe heat, and imparts to it a beautiful green color.

Chrome-ore is found at the Bare Hills, near Baltimore, in Maryland; in the Shetland Isles, Unst and Fetlar; the department of Var, in France, in small quantity; and near Portsoy, in Banffshire; as also in Silesia and Bohemia.

The chief application of this ore is to the production of chromate of potash, from which salt the various other preparations of this metal used in the arts are obtained. The ore, freed, as well as possible, from its gangue, is reduced to a fine powder, by being ground in a mill under ponderous edge-wheels, and sifted. It is then mixed with one third or one half its weight of coarsely bruised nitre, and exposed to a powerful heat, for several hours, on a reverberatory hearth, where it is stirred about occasionally. In the large manufactories of this country, the ignition of the above mixture in pots is laid aside, as too operose and expensive. The calcined matter is raked out, and lixiviated with water. The bright yellow solution is then evaporated briskly, and the chromate of potash falls down in the form of a granular salt, which is lifted out from time to time from the bottom with a large ladle, perforated with small holes, and thrown into a draining-box. This saline powder may be formed into regular crystals of neutral chromate of potash, by solution in water and slow evaporation; or it may be converted into a more beautiful crystalline body, the bichromate of potash, by treating its concentrated solution with nitric, muriatic, sulphuric, or acetic acid, or, indeed, any acid exercising a stronger affinity for the second atom of the potash than the chromic acid does.

Bichromate of potash, by evaporation of the above solution, and slow cooling, may be obtained in the form of square tables, with bevelled edges, or flat four-sided prisms. They are permanent in the air, have a metallic and bitter taste, and dissolve in about one tenth of their weight of water, at 60° F.; but in one half of their weight of boiling water. They consist of chromic acid 13, potash 6; or, in 100 parts, 68·4 + 31·6. This salt is much employed in calico-printing and in dyeing; which see.

Chromate of lead, the chrome-yellow of the painter, is a rich pigment of various shades, from deep orange to the palest canary yellow. It is made by adding a limpid solution of the neutral chromate (the above granular salt) to a solution, equally limpid, of acetate or nitrate of lead. A precipitate falls, which must be well washed, and carefully dried out of the reach of any sulphureted vapors. A lighter shade of yellow is obtained by mixing some solution of alum, or sulphuric acid, with the chromate, before pouring it into the solution of lead; and an orange tint is to be procured by the addition of subacetate of lead, in any desired proportion.

For the production of chromate of potash from chrome ore, various other processes have been recommended. The following formulæ, which have been verified in practice, will prove useful to the manufacturers of this important article:—

I. Two parts of chrome ore, containing about 50 per cent. of protoxyde of chromium:
One part of saltpetre.

II. Four parts of chrome ore, containing 31 per cent. of protoxyde of chromium.
Two parts of potashes.
One part of saltpetre.
III. Four parts of chrome ore. — 34 —
Two of potashes.
Four tenths of a part of peroxyde of manganese.
IV. Three parts of chrome ore.
Four parts of saltpetre.
Two parts of argal.

Some manufacturers have contrived to effect the conversion of the oxyde into an acid, and of course to form the chromate of potash, by the agency of potash alone, in a calcining furnace, or in earthen pots fired in a pottery kiln.

After lixiviating the calcined mixtures with water, if the solution be a tolerably pure chromate of potash, its value may be inferred, from its specific gravity, by the following table : —

At specific gravity	1·28	it contains about	50	per cent. of the salt.
	1·21		33	
	1·18		25	
	1·15		20	
	1·12		16	
	1·11		14	
	1·10		12	

In making the red bichromate of potash from these solutions of the yellow salt, nitric acid was at first chiefly used; but in consequence of its relatively high price, sulphuric, muriatic, or acetic acid has been frequently substituted upon the great scale.

There is another application of chrome which merits some notice here; that of its green oxyde to dyeing and painting on porcelain. This oxyde may be prepared by decomposing, with heat, the chromate of mercury, a salt made by adding to nitrate of protoxyde of mercury, chromate of potash, in equivalent proportions. This chromate has a fine cinnabar red, when pure; and, at a dull red heat, parts with a portion of its oxygen and its mercurial oxyde. From M. Dulong's experiments it would appear, that the purest chromate of mercury is not the best adapted for preparing the oxyde of chrome to be used in porcelain painting. He thinks it ought to contain a little oxyde of manganese and chromate of potash, to afford a green color of a fine tint, especially for pieces that are to receive a powerful heat. Pure oxyde of chrome preserves its color well enough in a muffle furnace; but, under a stronger fire, it takes a dead-leaf color.

The green oxyde of chrome has come so extensively into use as an enamel color for porcelain, that a fuller account of the best modes of manufacturing it must prove acceptable to many of my readers.

That oxyde, in combination with water, called the hydrate, may be economically prepared by boiling chromate of potash, dissolved in water, with half its weight of flowers of sulphur, till the resulting green precipitate ceases to increase, which may be easily ascertained by filtering a little of the mixture. The addition of some potash accelerates the operation. This consists in combining the sulphur with the oxygen of the chromic acid, so as to form sulphuric acid, which unites with the potash of the chromate into sulphate of potash, while the chrome oxyde becomes a hydrate. An extra quantity of potash facilitates the deoxydizement of the chromic acid by the formation of hyposulphite and sulphuret of potash, both of which have a strong attraction for oxygen. For this purpose the clear lixivium of the chromate of potash is sufficiently pure, though it should hold some alumina and silica in solution, as it generally does. The hydrate may be freed from particles of sulphur by heating dilute sulphuric acid upon it, which dissolves it; after which it may be precipitated, in the state of a carbonate, by carbonate of potash, not added in excess.

By calcining a mixture of bichromate of potash and sulphur in a crucible, chromic acid is also decomposed, and a hydrated oxyde may be obtained; the sulphur being partly converted into sulphuret of potassium, and partly into sulphuric acid (at the expense of the chromic acid), which combines with the rest of the potash into a sulphate. By careful lixiviation, these two new compounds may be washed away, and the chrome green may be freed from the remaining sulphur, by a slight heat.

Liebig and Wöhler have lately contrived a process for producing a subchromate of lead of a beautiful vermilion hue. Into saltpetre, brought to fusion in a crucible at a gentle heat, pure chrome yellow is to be thrown by small portions at a time. A strong ebullition takes place at each addition, and the mass becomes black, and continues so while it is hot. The chrome yellow is to be added till little of the saltpetre remains undecomposed, care being taken not to overheat the crucible, lest the color of the mixture should become brown. Having allowed it to settle for a few minutes, during which the dense basic salt falls to the bottom, the fluid part, consisting of

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chromate of potash and saltpetre, is to be poured off, and it can be employed again in preparing chrome yellow. The mass remaining in the crucible is to be washed with water, and the chrome red being separated from the other matters, is to be dried after proper edulcoration. It is essential for the beauty of the color, that the saline solution should not stand long over the red powder, because the color is thus apt to become of a dull orange hue. The fine crystalline powder subsides so quickly to the bottom after every ablution, that the above precaution may be easily observed.

As *Chromic Acid* will probably ere long become an object of interest to the calico printer, I shall describe here the best method of preparing it. To 100 parts of yellow chromate of potash, add 136 of nitrate of barytes, each in solution. A precipitate of the yellow chromate of barytes falls, which being washed and dried would amount to 130 parts. But while still moist it is to be dissolved in water by the intervention of a little nitric acid, and then decomposed by the addition of the requisite quantity of sulphuric acid, whereby the barytes is separated, and the chromic acid remains associated with the nitric acid, from which it can be freed by evaporation to dryness. On re-dissolving the chromic acid residuum in water, filtering and evaporating to a proper degree, 50 parts of chromic acid may be obtained in crystals.

This acid may also be obtained from chromate of lime, formed by mixing chromate of potash and muriate of lime; washing the insoluble chromate of lime which precipitates, and decomposing it by the equivalent quantity of oxalic acid, or for ordinary purposes even sulphuric acid may be employed.

Chromic acid is obtained in quadrangular crystals, of a deep red color; it has a very acrid and styptic taste. It reddens powerfully litmus paper. It is deliquescent in the air. When heated to redness it emits oxygen, and passes into the deutoxyde. When a little of it is fused along with vitreous borax, the compound assumes an emerald green color.

As chromic acid parts with its last dose of oxygen very easily, it is capable in certain styles of calico printing of becoming a valuable substitute for chlorine, where this more powerful substance would not from peculiar circumstances be admissible. For this ingenious application, the arts are indebted to that truly scientific manufacturer, M. Daniel Kœchlin, of Mülhouse. He discovered that whenever chromate of potash has its acid set free by its being mixed with tartaric or oxalic acid, or a neutral vegetable substance, (starch or sugar for example,) and a mineral acid, a very lively action is produced, with disengagement of heat, and of several gases. The result of this decomposition is the active reagent, chromic acid, possessing valuable properties to the printer. Watery solutions of chromate of potash and tartaric acid being mixed, an effervescence is produced which has the power of destroying vegetable colors. But this power lasts no longer than the effervescence. The mineral acids react upon the chromate of potash only when vegetable coloring matter, gum, starch, or a vegetable acid are present, to determine the disengagement of gas. During this curious change carbonic acid is evolved; and when it takes place in a retort, there is condensed in the receiver a colorless liquid, slightly acid, exhaling somewhat of the smell of vinegar, and containing a little empyreumatic oil. This liquid heated with the nitrates of mercury or silver reduces these metals. On these principles M. Kœchlin discharged indigo blue by passing the cloth through a solution of chromate of potash, and printing nitric acid thickened with gum upon certain spots. It is probable that the employment of chromic acid would supersede the necessity of having recourse in many cases to the more corrosive chlorine.

The following directions have been given for the preparation of a *blue oxyde* of chrome. The concentrated alkaline solution of chromate of potash is to be saturated with weak sulphuric acid, and then to every 8 lbs. is to be added 1 lb. of common salt, and half a pound of concentrated sulphuric acid; the liquid will now acquire a green color. To be certain that the yellow color is totally destroyed, a small quantity of the liquor is to have potash added to it, and filtered; if the fluid is still yellow, a fresh portion of salt and of sulphuric acid is to be added; the fluid is then to be evaporated to dryness, redissolved, and filtered; the oxyde of chrome is finally to be precipitated by caustic potash. It will be of a greenish-blue color, and being washed, must be collected upon a filter.

Chromate of Potash, adulteration of, to detect. The chromate of potash has the power of combining with other salts up to a certain extent without any very sensible change in its form and appearance; and hence it has been sent into the market falsified by very considerable quantities of sulphate and muriate of potash, the presence of which has often escaped observation, to the great loss of the dyers who use it so extensively. The following test process has been devised by M. Zuber, of Mülhouse. Add a large excess of tartaric acid to the chromate in question, which will decompose it, and produce in a few minutes a deep amethyst color. The supernatant liquor will, if the chromate be pure, afford now no precipitate with the nitrates of barytes or silver; whence the absence of the sulphates and muriates may be inferred. We must, however, use dilute solutions of the chromate and acid, lest bitartrate of potash be precipitated, which will take place if less than 60 parts of water be employed. Nor must

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we test the liquid till the decomposition be complete, and till the colour verge rather towards the green than the yellow. Eight parts of tartaric acid should be added to one of chromate to obtain a sure and rapid result. If nitrate of potash (saltpetre) is the adulterating ingredient, it may be detected by throwing it on burning coals, when deflagration will ensue. The green colour is a certain mark of the transformation of the chromic acid partially into the chrome oxide; which is effected equally by the sulphurous acid and sulphuretted hydrogen. Here this metallic acid is disoxygenated by the tartaric, as has been long known. The tests which I should prefer are the nitrates o silver and baryta, having previously added so much nitric acid to the solution of the suspected chromate, as to prevent the precipitation of the chromate of silver or baryta. The smallest adulteration by sulphates or muriates will thus be detected.

Chromium, Oxide of.—Mix intimately 45 parts of gunpowder with 240 parts of perfectly dry chromate of potash, and 35 parts of hydrochlorate of ammonia (sal ammoniac), reduce to powder, and pass through a fine sieve; fill a conical glass or other mould with this powder, gently pressed, and invert so as to leave the powder on a porcelain slab of any kind. When set on fire at its apex with a lighted match, it will burn down to the bottom with brilliant coruscations. The black residuum, being elutriated with warm water, affords a fine bright green oxide of chromium.

Chromium, *green oxide of.*—Ignite bichromate of potash with a quarter of its weight of flowers of sulphur, by projecting the mixture into a red hot crucible in small successive portions, stirring the pasty mass till the excess of sulphur is burnt off; pulverize the cooled mass, and wash with water till it affords no precipitate with chloride of barium or acetate of lead. The powder which remains on being gently dried is of a beautiful green color, and may be used as a pigment, or to prepare pure chromium.

CINNABAR; the native red sulphuret of mercury. It occurs sometimes crystallized in rhomboids; has a specific gravity varying from 6·7 to 8·2; a flat conchoidal fracture; is fine grained; opaque; has an adamantine lustre, and a color passing from cochineal to ruby red. The fibrous and earthy cinnabar has a scarlet hue. It is met with disseminated in smaller or larger lumps in veins, which are surrounded by a black clay, and is associated with native quicksilver, amalgam, with iron-ore, lead-glance, blende, copper-ore, gold, &c. Its principal localities are Almaden in Spain, Idria in the Schiefergebirge, Kremnitz and Schemnitz in Hungary; in Saxony, Bavaria, Bohemia, Nassau, China, Japan, Mexico, Columbia, Peru. It consists of two primes of sulphur, = 32·240, combined with one of mercury, = 202,863; or in 100 parts of 12·7 sulphur + 87·3 mercury. It is the most prolific ore of this metal; and is easily smelted by exposing a mixture of it with iron or lime to a red heat in retorts. Factitious cinnabar is called in commerce Vermilion, which see, as also Mercury.

CINNAMON. (*Cannelle*, Fr.; *Zimmt*, Germ.) Is the inner bark of the *laurus cinnamomum*, a handsome-looking tree which grows naturally to the height of 18 or 20 feet, in Java, Sumatra, Ceylon, and other islands in the East Indian seas. It has been transplanted to the Antilles, particularly Guadaloupe and Martinique, as well as Cayenne, but there it produces a bark of very inferior value to the Oriental.

Cinnamon is gathered twice a year, but not till after the tree has attained to a certain age and maturity. The young twigs yield a bark of better quality than the larger branches. The first and chief harvest takes place from April to August; the second, from November to January. After having selected the proper trees, all the branches more than three years old are cut off; the epidermis is first removed with a two-edged pruning knife, then a longitudinal incision is made through the whole extent of the bark, and lastly, with the bluntest part of the knife, the true bark is carefully stripped off in one piece. All these pieces of bark are collected, the smaller ones are laid within the larger, and in this state they are exposed to the sun, whereby in the progress of drying, they become rolled into the shape of a quill. These convoluted pieces are formed into oblong bundles of 20 or 30 lbs. weight, which are placed in warehouses, sorted and covered with mats. Good cinnamon should be as thin as paper, have its peculiar aromatic taste, without burning the tongue, and leave a sweetish flavor in the mouth The broken bits of cinnamon are used in Ceylon for procuring the essential oil by distillation. 445,367 lbs. of cinnamon were imported into this kingdom in 1835, of which 16,604 only were retained for internal consumption.

CITRIC ACID. (*Acide citrique*, Fr.; *Citronensaure*, Germ.) Scheele first procured this acid in its pure state from lemon juice, by the following process. The juice put into a large tub, is to be saturated with dry chalk in fine powder, noting carefully the quantity employed. The citrate of lime which precipitates, being freed from the supernatant foul liquor, is to be well washed with repeated affusion and decantation of water. For every 10 pounds of chalk employed, nine and a half pounds of sulphuric acid, diluted with six times its weight of water, are to be poured while warm upon the citrate of lime, and well mixed with it. At the end of twelve hours, or even sooner, the citrate will be all decomposed, dilute citric acid will float above, and sulphate of lime will be found at the bottom. The acid being drawn off, the calcareous sulphate must be thrown on a canvass filter, drained, and then washed with water to abstract the whole acid.

The citric acid thus obtained may be evaporated in leaden pans, over a naked fire till it acquires the specific gravity 1·13; after which it must be transferred into another vessel, evaporated by a steam or water bath till it assumes a syrupy aspect, when a pellicle appears first in patches, and then over the whole surface. This point must be watched with great circumspection, for if it be passed, the whole acid runs a risk of being spoiled by carbonization. The steam or hot water must be instantly withdrawn, and the concentrated acid put into a crystallizing vessel in a dry, but not very cold apartment. At the end of four days the crystallization will be complete. The crystals must be drained, re-dissolved in a small portion of water, the solution set aside to settle its impurities, then decanted, re-evaporated, and re-crystallized. A third or fourth crystallization may be necessary to obtain a colourless acid.

If any citrate of lime be left undecomposed by the sulphuric acid, it will dissolve in the citric acid, and obstruct its crystallization, and hence it will be safer to use the slightest excess of sulphuric acid, than to leave any citrate undecomposed. There should not, however, be any great excess of sulphuric acid. If there be, it is easily detected by nitrate of barytes, but not by the acetate of lead as prescribed by some chemical authors; because the citrate of lead is not very soluble in the nitric acid, and might thus be confounded with the sulphate, whereas citrate of barytes is perfectly soluble in that test acid. Sometimes a little nitric acid is added with advantage to the solution of the coloured crystals, with the effect of whitening them.

Twenty gallons of good lemon juice will afford fully ten pounds of white crystals of citric acid.

Attempts were made both in the West Indies and Sicily, to convert the lime and lemon juice into citrate of lime, but they seem to have failed through the difficulty of drying the citrate for shipment.

The crystals of citric acid are oblique prisms with four faces, terminated by dihedral summits, inclined at acute angles. Their specific gravity is 1·617. They are unalterable in the air. When heated, they melt in their water of crystallization; and at a higher heat, they are decomposed. They contain 18 per cent. of water, of which one-half may be separated in a dry atmosphere, at about 100° F., when the crystals fall into a white powder.

Citric acid in crystals is composed by my analysis of carbon, 35·8, oxygen 59·7, and hydrogen 45; results which differ very little from those of Dr. Prout, subsequently obtained. I found its atomic weight to be 8·375, compared to oxygen 1,000. I cannot account for Berzelius's statements relative to the composition of this acid.

Citric acid in somewhat crude crystals is employed with much advantage in calico-printing. If adulterated with tartaric acid, the fraud may be detected by adding potash to the solution of the acid, which will cause a precipitate of cream of tartar.

The manufacture of citric acid so closely resembles that of tartaric acid, that the makers of one commonly fabricate the other. The raw material in this case is pretty generally a black fluid, like thin treacle, which comes from Sicily, and is obtained by inspissating the expressed juice of the lemon,—the rind having previously been removed from the lemon for the sake of its essential oil. This black juice is impure citric acid, and requires to be treated with chalk, as practised with respect to the first operation on tartar; by which means, an insoluble citrate of lime is formed; and this, after being well washed with cold water, is decomposed by sulphuric acid; and the solution, after undergoing the action of animal charcoal and proper evaporation, yields brownish crystals on cooling. These are re-dissolved, discoloured, and crystallized three or four times ere they can be sent into the market, for citric acid is more tenacious of colouring matter than most of the other vegetable acids. At Nice, and in the South of France, a portion of chloride of lime is digested upon the citrate of lime, to bleach it prior to decomposition by sulphuric acid. For this purpose, the washed citrate is exposed in shallow vessels to the action of the sun's rays, covered by a weak solution of chloride of lime. In a few hours decolouration ensues; and it is moreover stated that the mucilage which hangs about the citrate of lime, and impedes the subsequent crystallization of the acid, is in this way destroyed, and the number of re-crystallizations requisite to give a saleable aspect to the citric acid thereby diminished. The use of chloride of lime for this purpose seems unknown, or, at least, is not practised in England. Of the samples of citric acid shown in the Great Exhibition, those from Howards and Kent, of Stratford, Pontifex and Wood, of Millwall, and J. Huskisson, of Gray's Inn Road, were extremely beautiful; and in respect to size and crystalline form surpassed anything exhibited in the French, Prussian, or Italian departments.

CIVET. (*Civette*, Fr.; *Zibeth*, Germ.) This substance approaches in smell to musk and ambergris; it has a pale yellow colour, a somewhat acrid taste, a consistence

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like that of honey, and a very strong aromatic odour. It is the product of two small quadrupeds of the genus *viverra* (*v. zibetha* and *v. civetta*), of which the one inhabits Africa, and the other Asia. They are reared with tenderness, especially in Abyssinia. The civet is contained in a sac, situated between the anus and the parts of generation, in either sex. The animal frees itself from an excess of this secretion by a contractile movement which it exercises upon the sac, when the civet issues in a vermicular form and is carefully collected. The negroes are accustomed to increase the secretion by irritating the animal; and likewise introduce a little butter, or other grease, by the natural slit in the bag, which mixes with the odoriferous substance, and increases its weight. It is employed only in perfumery.

According to M. Boutron-Chalard, it contains a volatile oil, to which it owes its smell, some free ammonia, resin, fat, an extractiform matter, and mucus. It affords by calcination an ash, in which there are some carbonate and sulphate of potash, phosphate of lime, and oxide of iron.

CLAY (*Argile*, Fr.; *Thon*, Germ.) is a mixture of the two simple earths, alumina and silica, generally tinged with iron. Lime, magnesia, with some other colouring metallic oxides, are occasionally present in small quantities in certain natural clays.

The different varieties of clay possess the following common characters:—

1. They are readily diffusible through water, and are capable of forming with it a plastic ductile mass, which may be kneaded by hand into any shape. This plasticity exists, however, in very different degrees in the different clays.

2. They concrete into a hard mass upon being dried, and assume, upon exposure to the heat of ignition, a degree of hardness sometimes so great as to give sparks by collision with hardened steel. In this state they are no longer plastic with water, even when pulverised. Tolerably pure clays, though infusible in the furnace, become readily so by the admixture of lime, iron, manganese, &c.

3. All clays, even when previously freed from moisture, shrink in the fire in virtue of the reciprocal affinity of their particles; they are very absorbent of water in their dry slate, and adhere strongly to the tongue.

4. Ochrey, impure clays emit a disagreeable earthy smell when breathed upon.

Brongniart distributes the clay into:—

1. Fire-clays, (*argiles apyres*, Fr.; *feuerfeste*, Germ.)
2. Fusible, (*schmelzbare*, Germ.)
3. Effervescing (*brausende*, Germ.) from the presence of chalk.
4. Ochrey (*ocreuses*, Fr.; *ockrige*, Germ.)

Fire-clay is found in the greatest abundance and perfection for manufacturing pur poses in,

1. *Slate-clay.* (*Thon-schiefer*, Germ.) Its colour is gray or grayish yellow. Massive, dull, or glimmering from admixture of particles of mica. Fracture slaty, approaching sometimes to earthy. Fragments tabular. Soft, sectile, and easily broken. Sp. gr.= 2·6. Adheres to the tongue, and breaks down in water. It occurs along with *pit coal;* which see. Slate-clay is ground, and reduced into a paste with water, for making fire-bricks; for which purpose it should be as free as possible from lime and iron.

2. *Common clay or loam.*—This is an impure coarse pottery clay, mixed with iron ochre, and occasionally with mica. It has many of the external characters of plastic clay. It is soft to the touch, and forms, with water, a somewhat tenacious paste; but is in general less compact, more friable, than the plastic clays, which are more readily diffusible in water. It does not possess the property of acquiring in water that commencement of translucency which the purer clays exhibit. Although soft to the touch, the common clay wants unctuosity, properly so called. The best example of this argillaceous substance is afforded in the London clay formation, which consists chiefly of bluish or blackish clay, mostly very tough. Those of its strata which effervesce with acids partake of the nature of marl. This clay is fusible at a strong heat in consequence of the iron and lime which it contains. It is employed in the manufacture of bricks, tiles, and coarse pottery ware.

3. *Potter's clay, or Plastic clay.*—This species is compact, soft, or even unctuous to the touch, and polishes with the pressure of the finger; it forms, with water, a tenacious, very ductile, and somewhat translucent paste. It is infusible in a porcelain kiln, but assumes in it a great degree of hardness. Werner calls it *pipe-clay.* Good plastic clay remains white, or if gray before, becomes white in the porcelain kiln.

The geological position of the plastic clay is beneath the London clay, and above the sand which covers the chalk formation. The plastic clay of the Paris basin is described as consisting of two beds separated by a bed of sand. The lower bed is the proper plastic clay. The plastic clay of *Abondant*, near the forest of Dreux, analyzed by Vauquelin, gave—

Silica, 43·5; alumina, 33·2; lime, 0·35; iron, 1; water, 18.

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This clay is employed as a fire clay for making the bungs or *seggars*, or coarse earthenware cases, in which china ware is fired.

The plastic clay of Dorsetshire and Devonshire supplies the great Staffordshire potteries. It is gray-coloured, less unctuous than that of Dreux, and consequently more friable. It becomes white in the pottery kiln, and is infusible at that heat. It causes no effervescence with nitric acid, but falls down quickly in it, and becomes higher coloured. Its refractoriness allows of a harder glaze being applied to the ware formed from it without risk of the heat requisite for making the glaze flow affecting the biscuit either in shape or colour. "Most of the plastic clays of France," says M. Brongniart, "employed for the same ware, have the disadvantage of reddening a little in a somewhat strong heat; and hence it becomes necessary to coat them with a soft glaze, fusible by means of excess of lead at a low heat, in order to preserve the white appearance of the biscuit. Such a glaze has a dull aspect, and cracks readily into innumerable fissures by alternations of hot and cold water." Hence one reason of the vast inferiority of the French stone-ware to the English.

4. *Porcelain clay or Kaolin earth.*—The Kaolins possess very characteristic properties. They are friable in the hand, meagre to the touch, and difficultly form a paste with water. When freed from the coarse and evidently foreign particles interspersed through them, they are absolutely infusible in the porcelain kiln, and retain their white colour unaltered. They harden with heat like other clays, and perhaps in a greater degree; but they do not acquire an equal condensation or solidity, at least when they are perfectly pure. The Kaolins in general appear to consist of alumina and silica in nearly equal proportions. Most of the Kaolin clays contain some spangles of mica which betray their origin from disintegrated granite.

This origin may be regarded as one of their most distinctive features. Almost all the porcelain clays are evidently derived from the decomposition of the felspars, granites, and principally those rocks of felspar and quartz, called graphic granite. Hence they are to be found only in primitive mountain districts, among banks or blocks of granite, forming thin seams or partings between them. In the same partings, quartz and mica occur, being relics of the granite; while some seams of Kaolin retain the external form of felspar.

The most valuable Kaolins have been found:—

In China and Japan. The specimens imported from these countries appear pretty white; but are more unctuous to the touch, and more micaceous than the porcelain clays of France.

In Saxony. The Kaolin employed in the porcelain manufactories of that country has a slight yellow or flesh colour, which disappears in the kiln, proving, as Wallerius observed, that this tint is not owing to any metallic matter.

In France, at Saint-Yriex-la-Perche, about 10 leagues from Limoges. The Kaolin occurs there in a bed, or perhaps a vein of beds of granite, or rather of that felspar rock called Pe-tun-tse, which exists here in every stage of decomposition. This Kaolin is generally white, but sometimes a little yellowish, with hardly any mica. It is meagre to the touch, and some beds include large grains of quartz, called pebbly by the China manufacturers. This variety, when ground, affords, without the addition of any fusible ingredient, a very transparent porcelain.

Near Bayonne. A Kaolin possessing the lamellated structure of felspar, in many places. The rock containing it is a graphic granite in every stage of decomposition.

In England in the county of Cornwall. This Kaolin or China clay is very white, and more unctuous to the touch than those upon the continent of Europe mentioned above. Like them it results from the decomposition of the felspars and granites, occurring in the middle of these rocks. Mr. Wedgewood found it to contain 60 of alumina or pure clay, and 40 of silica, in 100 parts.

Pure clay, the alumina of the chemist, is absolutely infusible; but when subjected to the fire of a porcelain kiln, it contracts into about one-half of its total bulk. It must, however, be heated very cautiously, otherwise it will decrepitate and fly in pieces, owing to the sudden expansion into steam of the water combined with its particles, which is retained with a considerable attractive force. It possesses little plasticity, and consequently affords a very short paste, which is apt to crack when kneaded into a cake.

It is not only infusible by itself, but it will not dissolve in the fusible glasses; making them merely opaque. If either lime or silica be added separately to pure clay, in any proportion, the mixture will not melt in the most violent furnace; but if alumina, lime, and silica be mixed together, the whole melts, and the more readily, the nearer the mixture approaches to the following proportions:—1 of alumina, 1 of lime, and 3 of sand. If the sand be increased to five parts, the compound becomes infusible. These interesting facts show the reciprocal action of those earths which are mixed most commonly in nature with alumina.

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Iron in small quantity, but in a state not precisely determined, though probably of protoxide, does not colour the clays till they are subjected to a powerful heat. There are very white clays, such as those of Montereau, which do not become red till calcined in the porcelain kiln; the oxide of iron contained in them, which colours them in that case, was previously imperceptible. It appears from this circumstance, that the clays fit for making fine white stone ware, as also the Kaolins adapted to the manufacture of porcelain, are very rare.

Iron in larger proportion, usually colours the clays green or slate-blue, before they have been heated. Such clays, exposed to the action of fire, become yellow or red according to the quantity of iron which they contain. When the iron is very abundant, it renders the clays fusible; but a little lime and silica must also be present for this effect. The earthenware made with these ferruginous clays can bear but a moderate baking heat; it is thick, porous, and possesses the advantage merely of cheapness, and of bearing considerable alternations of temperature without breaking.

Alumina and the very aluminous natural clays which possess most plasticity are apt to crack in drying, or to lose their shape. This very serious defect for the purposes of pottery is rectified, in some measure, by adding to that earth a certain quantity of sand or silica. Thus, a compound is formed which possesses less attraction for water and dries more equably from the openness of its body. The principal causes of the distortion of earthenware vessels, are the unequal thickness of their parts, and quicker desiccation upon one side than another. Hard burnt stone-ware ground to powder, and incorporated with clay, answers still better than sand for counteracting the great and irregular contraction which natural pottery paste is apt to experience. Such ground biscuit is called *cement;* and its grains interspersed through the ware, may be regarded as so many solutions of continuity, which arrest the fissures.

The preceding observations point out the principles of those arts which employ clay for moulding by the wheel, and baking in a kiln. See PORCELAIN and POTTERY.

The chemical composition of the clays shown at the Great Exhibition was unfortunately not given, as it ought to have been. The injurious effect of this ignorance will, by-and-by, come under consideration, when speaking of the art of the potter; but, for the present, we shall content ourselves with a hasty glance at the various specimens of clay exhibited in Class I.,—adding, as usual, a few practical hints for the analysis of these substances, together with some analytical investigations recently made upon average market samples of clay, for the express purpose of elucidating this obscure subject. In a manufacturing point of view, clays may be conveniently divided into three classes; for although a fourth (that is to say, common marl clay) exists, yet, as its employment is limited to the making of bricks and other coarse articles in which improvement is nearly hopeless, so far as regards material, we shall confine our observations to the three finer qualities, named, respectively, china clay or kaolin, fire-clay, and potter's clay. In china clay, Jenkins & Courtney, of Truro; Whitley of Truro; C. Thriscutt, of St. Austell; the West of England China Stone and Clay Company; Truscott, Martyn, Brown, Michell, and Wheeler, Philip & Co., all of St. Austell; and W. Phillips, of the Morley Works, near Plympton, together with Sir G. Hodson, Bart., of Wicklow in Ireland, exhibit some samples of great beauty and apparent purity. In fire-clay, the articles shown by King & Co., Squires & Son, and F. T. Rafford, of Stourbridge, with those from Cowan & Co., Ramsey & Co., and Potter, of Newcastle, are excellent; and a sample from Pease of Darlington, also deserves notice. In potter's clay, Whiteway, Watts, & Co., of Dorset; Fayle & Co., of Thames Street, London; W. & J. Peike, of the Isle of Purbeck; N. Burnet, of Gateshead; and the North Devon Pottery Company, are the most remarkable, though there are many very respectable looking samples from other quarters.

In the manufacture of earthenware goods, it is indispensably necessary to mix the clay, in the first instance, with some infusible material, which does not contract or diminish under the influence of heat; for all kinds of clay shrink very much by the action of a high and prolonged temperature, and are therefore liable, during such exposure, to warp and twist out of shape, or become cracked in the furnace. Hence a remedy is sought as above indicated, and for this purpose, silica, in a minute state of division, is generally preferred; though felspar, and a kind of decomposing granite, called Cornish stone, are also used. But whatever may be the material, its introduction into the body of the earthenware is conducted on purely empirical principles, for, as the composition of the clay is unknown, no attempt can be or is made to effect a combination in unison with the laws of chemical affinity. The substances employed are recognised only as clay, and perhaps ground flint; nor is any other test used to ascertain the proper proportion of each towards the other, than the uncertain judgment of a workman, or the equally fallacious practice of an established rule. As, however, all clays, in a state of natural purity, consist of silica and alumina, united together in definite atomic proportions, there can be no doubt that perfection in earthenware depends upon this simple law; and

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that the only true mode of fabricating a uniform and really valuable kind of pottery-ware, would be to follow out the indications of nature, and constantly preserve an atomic ratio in the admixture of the flint and clay of which that pottery-ware is composed. Of course, under existing circumstances, this is impossible; for, as we have previously remarked, the precise composition of the different clays used in the arts is totally unknown; and, independent of any chemical difficulties that may be presumed to exist in determining this important fact for themselves, our manufacturers may justly plead that no simple and satisfactory mode of analyzing clay has yet been published. Hence the present empirical system is universal; and the accidental admixtures it produces testify to the truth of our remarks, by cracking and flying to pieces under very trivial alterations of temperature, no less to the annoyance than loss of the public at large. Nor can this be wondered at, when it is remembered that, in almost every tea-cup, saucer, or plate upon our tables, the laws of natural combination have been violated by the prevalence of an artificial and incompatible form of arrangement, the work of sheer ignorance and chance. So far as our investigations have yet gone, it appears that kaolin, or china clay, has arisen from the decomposition of felspar under two different conditions; for the resulting compound is not alike in both cases; though to what cause this difference can be ascribed we are unable with certainty to say. Felspar, in it original state, has exactly the same composition as anhydrous alum, with this exception, that in the one case the bases are united to sulphuric, and in the other to silicic acid. Felspar, therefore, consists of one atom of potash and one of silica, united to two atoms of alumina and three of silica; or, in other words, it is formed of the silicate of potash and the silicate of alumina, combined in the ratio of one atom of the former to two of the latter. Now, it is found that, when felspar is long exposed to the action of the weather, it becomes disintegrated and falls into a state of powder, which, ultimately, by absorbing water, assumes a pasty consistence, and thus forms the article called china clay. The nature of this decomposition is not, however, uniform or invariable, for analysis proves that the residuary produce has not always the same composition. When felspar decomposes in an absolutely wet or rainy atmosphere, the silicate of potash would appear to be simply washed away by the excess of water; and, in this case, the resulting clay has a composition of three atoms of silica and two of alumina; but, when merely a moist atmosphere has existed, then the silicate of potash itself seems to become decomposed, probably by carbonic acid, thus leaving the whole of the silica united to the alumina; the potash then escaping as a carbonate. Under such circumstances, we have found china clay to consist of four atoms of silica and two of alumina; or, what is the same thing, of two of acid and one of base. Of course an alternating atmosphere would produce a mixture of these; and such layers may actually be traced in many specimens of clay, as though the summer and winter portions of the year had each furnished a distinctly separate amount of decomposed felspar. But felspar is not the only source from whence our silicate of alumina has been formed; as there are many other minerals which, by the action of the atmosphere, furnish clays of different compositions: thus, the substances known to mineralogists under the names leucite, albite, analcime, nepheline, mesotype, and sodalite, all yield silicate of alumina, which contains, indeed, various proportions of the two ingredients, but is nevertheless, in a commercial sense, clay. In point of fact even granite has contributed its quota to the clay formation, for though slowly and imperfectly, yet in time it crumbles down into supersilicate of alumina: as may be noticed by carefully examining the once smooth surface of the granite on Waterloo and London Bridges, which is gradually assuming a cavernous character. With such evidence before us of the infinite variety existing in clay, it is surely high time that the attention of manufacturers was directed to the necessity of analyzing this substance, and adding to it neither more nor less silica than is sufficient to produce a useful atomic compound. The proper proportion might soon be arrived at by a few carefully conducted experiments, after which the whole of the uncertainty now connected with differences in the material would vanish for ever, and with it no small amount of the loss occasionally caused by earthenware spoilt or broken in the kiln.

To determine the quantity of alumina in clay, a given weight of this substance, say 100 grs., well dried and in fine powder, should be mixed with double its weight of fluor spar, also in fine powder, then the mixture placed in a platinum or leaden vessel, and about 400 grs. of strong sulphuric acid poured over it. Next expose the whole to a heat of from 212° to 250° Fahr. for half an hour; then add three or four ounces of water, and throw the mixture on a filter, adding a little water at the end of the filtration, so as to obtain the whole of the soluble matter. To the filtered fluid add now an excess of a solution of ammonia, by which the alumina will be precipitated, and this, after being well washed on a filter, and dried at a red heat, must have its amount determined by the balance. If, however, the precipitate thrown down by ammonia has a deep yellow or red colour, the presence of iron is indicated; and this must be removed before drying the alumina. For this purpose, a quantity of tartaric acid should be added, so as to redissolve the mixed precipitate, and the solution slightly supersaturated with carbonate of soda when, on adding hydrosulphate of ammonia, the iron will separate as a black sulphuret, leaving the alumina still in solution; from whence it may be obtained by evaporating the whole to dryness, heating red hot, and then washing away the alkaline salts by hot water; the alumina is then left pure, and, after being dried, may be weighed. As the presence of iron in clay is a serious drawback, the quantity of black sulphuret formed becomes a good indication of the impurity of the sample under examination, and is therefore worthy of notice.

Although the proportion of alumina in clay is the chief commercial feature required by the makers of earthenware, yet it may sometimes be requisite to determine also the amount of silica present; which may be done by fusing together in an iron crucible or pan, at a full red heat, one part of the clay in question with three parts of pure potash,—both being in fine powder, and carefully mixed before fusion. The fused mass must, when cold, be boiled for some time in water, until it is thoroughly disintegrated; when it should be poured into a porcelain vessel, and supersaturated with muriatic acid; after which, by evaporating to dryness, a residue will be obtained, that, after careful washing with boiling water, consists merely of the silica contained in the clay in question. After being heated red hot, it may be weighed as usual. If lime be suspected to exist with the alumina in clay, this may be separated, when in solution, by means of tartaric acid and carbonate of soda, as above indicated; for in such cases, the lime will fall at once as a carbonate, leaving the alumina behind in the fluid. Independent, however, of the defects in British earthenware due to the non-atomic admixture of its ingredients, there are others arising out of the nature of the ingredients themselves; so that, taken as a whole, we cannot avoid coming to the unpleasant conclusion, that, in the great arena of competition at the Crystal Palace, England is decidedly beaten in the manufacture of fine earthenware, even by countries greatly its inferiors in capital, intelligence, and natural resources. France, Germany, Sweden, Denmark, Spain, Russia, Turkey, and China, all exhibited porcelain of a quality unmatched by anything in the British department, and no more lamentable contrast could possibly be drawn than between the chemical apparatus from Saxony and the clumsy abortions, which, under that name, disfigured some of the compartments claimed by one or two of our Staffordshire manufacturers. In the one case we find a really handsome, light, and elegant article, the glaze of which has evidently penetrated throughout the entire substance of the body, and has converted the whole into a uniform vitrification; in the other, a thick, coarse, opaque, and spongy mass, is merely glazed over on its extreme surface by a fusible compound, having no properties in common with the body of the article, and endowed with very different powers of expansibility by heat; so that, after being used a few times, the glaze becomes cracked and shivered in a thousand directions, as may be seen by examining the earthenware in common use throughout Great Britain. Nor is the unsightly appearance caused by this cracking of the glaze the whole evil; for earthen vessels thus flawed acquire the property of absorbing fluids into their pores, and can never afterwards be thoroughly cleaned. In spite, therefore, of "warranted not to absorb," and other groundless legends of similar import, imprinted upon many British goods, a piece of really non-absorbent earthenware, for common use, is an actual curiosity in this country, and invariably suggests the idea of a foreign origin. Now this defect can be remedied only in two ways; and, as our manufacturers have vainly endeavoured to carry out, practically, one of these ways, we are not without hopes of persuading them to try the other. If a glazing material could be discovered, the expansions and contractions of which, by heat, exactly corresponded with those of the biscuit ware, or silicate of alumina, under the same influence, then the present system of covering a spongy body by a coating of vitrifiable glaze would answer the desired intention well enough; for to the cheapness and durability of earthenware would thus be superadded the cleanliness of glass. But this desideratum has been sought for, over and over again, during the last half century, and nothing but disappointment has resulted. In proof of which we have only to ask—where is that glazed earthen vessel, which, though made expressly for the use of the apothecary, will retain oil, after being two or three times heated and cooled? The answer to this question must be our argument in favour of abandoning such a system of glazing, and adopting the only other mode by which a non-absorbent pottery ware can be fabricated. The body of the ware itself must undergo a semivitrification, as happens with the finest kind of china; so that, even if by long use the glaze come to be fairly worn off, still the non-absorbent principle would remain as perfect as at first. We know that this is impracticable under existing circumstances; and that, so long as the present empirical mode of compounding the materials of which the body of the ware is made continues, no chance of improvement remains. A mixture of silica and alumina, in the proportion of four atoms of the former to one of the latter, would bear or require a certain quantity of fusible material to induce semivitrification throughout the mass; but a compound of three atoms of silica and one of alumina would probably be melted down into a worthless slag by exactly the same addition. Here then lies the root of that difficulty which has hitherto so injuriously restricted the employment of felspar and other vitrifiable bodies in the fabrication of British earthenware. Those who have attempted to use such substances have occasionally succeeded to admiration; and nothing but the uncertainty of the result, and repeated failures, have induced them to abandon the employment of a class of articles which, if capable of being controlled, every intelligent manufacturer admits would confer perfection on his art. But it is a great mistake to suppose that these inequalities of action arise out of some peculiarity in the vitrifiable materials themselves, or are in any way the work of chance. The materials are, or ought to be, uniform, and certainly can be made so, whilst, for the rest, there is no such thing as chance in nature,—the laws of chemistry are not accidental or variable, they are immutable. We have shown, however, that clays not only differ from each other, but, as it were, from themselves; since, from the same pit, and within a few inches of the same spot, clays of very contrary characters may be procured. Plasticity is no more an indication of the presence or purity of clay, than sweetness is a test of sugar. In a rough way both these qualities have a value; but the arts are now fast approaching an epoch, when all such fallacious aids must give place to the guidance of philosophy; and the sooner our manufacturers become convinced of this grand truth the better for themselves and their country. The propriety of knowing the exact composition of the raw materials employed in any art or manufacture does not, indeed, admit of dispute—it is imperative; and hence we are the more astonished at the scantiness of information respecting the analysis of so important a production as clay. In face of such apathetic ignorance, would any one believe that, independently of an immense home consumption, our exports of earthenware last year amounted to a million sterling? Had the clays of this country been of a tolerably uniform composition, like some of those in China and on the continent, of course mere practice would long ago have enabled our potters to produce articles of the highest quality. But surely this is a sorry compliment to men surrounded by all the resources of science and capital. Where there is no difficulty there can be but little merit, and still less profit. It is the great glory of British enterprise and industry to despise so low and facile a position. Our manufacturers must meet and overcome the trivial impediments connected with variations in the clay they purchase, and, by properly adjusting the other materials (so as to bring on exactly the due amount of vitrification needed in the body of the ware), produce, from any kind of clay, articles identical with those which other nations fabricate from the very finest clays only. With the prodigious commercial and other advantages possessed by Great Britain, the world at large ought to expect this at our hands, and not the sub-mediocre workmanship displayed in the Great Exhibition.

Before quitting this subject, a few remarks upon the substances used in the formation of glazes may not be inappropriate. The million is still supplied with earthenware, the glaze of which contains lead, and is, consequently, dangerous to health, though, when well burned on, this danger is greatly diminished, from the increased insolubility of the silicate of lead in weak acids. It is, however, an objectionable mode of glazing earthenware, and requires to be watched with caution, more especially where borax is used at the same time, for the borate of lead is more easily acted on than the silicate. It has been lately suggested that oxide of zinc would form a sufficiently fusible compound with silica, and is cheap enough to supplant oxide of lead in the glazing of common earthenware. The latter assertion is undoubtedly true, and, although we entertain some suspicions as to the easy fusibility of silicate of zinc, yet this is precisely one of those problems which, from their important sanitary bearing, deserve immediate investigation. On the continent a very pure kind of felspar, mixed probably with a little carbonate of baryta and oxide of tin, forms the only glaze used upon porcelain and the china vessels intended for chemical purposes. This glaze is practically perfect. It is so hard as to withstand the attack of a file, and it resists the action of the strongest acids and alkalis at all temperatures below 300° Fahr.—the hydrofluoric acid and its salts alone excepted. In the French, Saxon, and Prussian departments of the Crystal Palace, there were several good specimens which illustrated the value of this kind of glaze

Amongst the English goods—and chiefly those from Staffordshire—were a variety of articles made in what is termed Parian, a compound, the unfitness of which for statuary purposes we now briefly animadvert upon, with reference however only to its employment in the higher branches of Decorative Art. The employment of this material, or indeed any other form of alumina where sharpness and symmetry are wanted, cannot be sufficiently condemned, since it is totally contrary to the natural properties of alumina, and betrays infinite ignorance regarding first principles. The philosophical mind of Wedgewood would have revolted at so palpable an absurdity; for not alone was he well acquainted with the continuous contractility of aluminous compounds, but, taking advantage of that knowledge, he was able to construct an instrument for measuring high degrees of heat, which, although not rigidly perfect, is at this day still found the only available guide for furnace operations on a large scale. And the value of this instrument or pyrometer, as it is termed, depends upon the fact, that the longer and higher the temperature to which clay is exposed, the smaller it becomes. Now bearing in mind that earthenware is an extremely bad conductor of heat, let us imagine the Greek Slave, for example, correctly modelled in clay or Parian, and subjected to the heat of a porcelain furnace. The smaller portions of the figure, as the nose, eyelids, fingers, &c., would receive much more of the impress of the fire than the larger ones,—as the head, shoulders, &c.; consequently, however symmetrical the original model might have been, the extra contraction in the smaller parts must destroy every thing like anatomical harmony and beauty. The fingers would become short and dumpy, and the nose flat and snubbed. But this is a small part of the mischief, for since clay, when burnt, is a bad conductor of heat, and the action of the fire is from without to within, the exterior of the figure must contract vastly more than the interior; consequently, the outside becoming too small for the inside, a series of cracks or fissures make their appearance to compensate for the inequality. These, of course, are filled up by a subsequent operation; but, it is needless to add, at the expense of every thing which would have rendered the result valuable as a work of art. The general appearance of the Parian figures shown in the Exhibition bears us out in this censure; for the features are universally flat, soulless, and devoid of expression; nor can we imagine a more hopeless task than attempting to remedy this defect.

CLOTH, MANUFACTURE OF. See Cotton, Flax, Weaving, Wool.

CLOTH-BINDING. Nothing places in so striking a point of view the superior taste, judgment, and resources of London tradesmen over those of the rest of the world, than the extensive substitution which they have recently made of embossed silks and calicoes for leather in the binding of books. In old libraries, cloth-covered boards indeed may occasionally be seen, but they have the meanest aspect, and are no more to be compared with our modern cloth-binding, than the *jupon* of a trull with the ballet dress of Taglioni. The silk or calico may be dyed of any shade which use or fancy may require, impressed with gold or silver foil in every form, and variegated by ornaments in relief, copied from the most beautiful productions in nature. This new style of binding is distinguished not more for its durability, elegance, and variety, than for the economy and dispatch with which it ushers the offspring of intellect into the world. For example, should a house eminent in this line, such as that of Westleys, Friar-street, Doctor's-commons, receive 5000 volumes from Messrs. Longman & Co. upon Monday morning, they can have them all ready for publication within the incredibly short period of two days; being far sooner than they could have rudely boarded them upon the former plan. The reduction of price is not the least advantage incident to the new method, amounting to fully 50 per cent. upon that with leather.

The dyed cloth being cut by a pattern to the size suited to the volume, is passed rapidly through a roller press, between engraved cylinders of hard steel, whereby it receives at once the impress characteristic of the back, and the sides, along with embossed designs over the surface in sharp relief. The cover thus rapidly fashioned, is as rapidly applied by paste to the stitched and pressed volume; no time being lost in mutual adjustments; since the steel rollers turn off the former of a shape precisely adapted to the latter. Hard glazed and varnished calico is moreover much less an object of depredation to moths and other insects, than ordinary leather has been found to be.

CLOTH-DRESSING, *by Heycock of Leeds*, without stretching the warp-threads or creasing the cloths from list to list. He lays several pieces of cloth in an extended state above one another upon a wooden platform, until a pile of a suitable thickness is formed, a perforated plate is then brought down on the cloth by screws, and steam is admitted into a hollow chamber beneath, from which it penetrates all the folds of the cloth, but is confined at the sides. It seems to be a purpose-like invention.

COAL. Under Pitcoal, the composition of several excellent coals is stated, with their peculiar qualities, as analyzed by me; such as the Llangenneck, Powell's Duffryn steam coal, the Blackley Hurst coal, Lancashire, the Varley Rock vein coal, near Pontypool, &c. The quantity of coals and culm exported in 1850 was 3,351,880 tons, and in 1851, 3,477,060 tons; declared value respectively, 1,284,224*l.* and 1,302,025*l.*

COAL GAS. From what is generally admitted concerning the impurities which exist in crude coal-gas, it must be evident to those conversant with the principles of chemistry that these impurities can never be thoroughly removed by any single reagent, for some of them possess affinities diametrically opposite to the others. Thus, any means employed to absorb carbonic acid and sulphuretted hydrogen gases would leave the ammonia free; whilst an agent capable of combining with the latter, would not at all affect the former impurities. Hence the process of coal gas purification, as now carried on at the best gas works, is divided into two distinct parts. By one of these the whole of the ammonia and a portion of the carbonic acid and sulphuretted hydrogen are taken away, by the other, the remainder of the carbonic acid and sulphuretted hydrogen are totally removed; so that the gas ultimately passes forth to the consumer free from all contamination either by ammonia, carbonic acid, or sulphuretted hydrogen gas. And the absence of these impurities may at any time be demonstrated by applying the following simple tests: — litmus paper, slightly reddened by an acid, will undergo no change when held for a few minutes in a current of the gas; this proves the absence of ammonia, for otherwise the paper would become blue. Paper, dipped into a solution of the acetate of lead, and held in a current of the gas, will remain white, which shows that the gas is destitute of sulphuretted hydrogen, as, under contrary circumstances, it would assume a deep brown or black hue. Lastly, if the gas be allowed to blow for a few minutes through a clear solution of lime in water, the solution will not become milky and turbid, as it would do if carbonic acid were present in the gas. No coal gas which does not vindicate its purity by resisting the analytical powers of the above tests can be regarded as sufficiently good for the purposes of illumination and heating.

To separate the ammonia from coal gas, a variety of modes is at present in use; thus, Mr. Lowe employs cold water minutely divided in an apparatus which he terms a "scrubber," and which is perfectly analogous to the *cascade chimique* of Clement Desormes. With a similar view Mr. Palmer mixes the gas with steam, and then subjects the mixture to a condensing temperature, so as to obtain water, minutely divided in drops, like rain or dew, and therefore presenting a considerable surface for chemical action. Mr. Johnson prepares a compound, consisting of sulphate and biphosphate of lime, by acting on burnt bones with sulphuric acid; and this he disposes in trays, so as to absorb the ammonia and produce a mixture of sulphate of ammonia and phosphate of lime, which, as might be expected, he finds an extremely efficient fertilizing agent. Mr. Laming employs a solution of chloride of calcium or muriate of lime, absorbed into sawdust, which he disposes in the same manner as that followed by Mr. Johnson, and by which the muriate of lime is gradually decomposed with the formation of carbonate of lime and muriate of ammonia,—the resulting compound being either valuable as a manure, or as a source for the manufacture of sal ammoniac. Sulphate of lime, and various other earthy metallic salts, have also been proposed and employed,—such as the sulphates of magnesia, alumina, zinc, iron, and manganese, and the chlorides of the same metals. With the exception of the sulphate of lime, they do not, however, seem to possess any advantage over the modes we have mentioned as now in use for the absorption of ammonia; and hence it may be as well to examine more minutely the actions of those methods, and their effects upon the gas undergoing purification. The process of Lowe is extremely simple in theory, and, where the saving of the ammonia is not an object of importance, has much to recommend it. Here the ammonia is, so to say, washed out by means of water; and the application of the scrubber may either be made before or after the other impurities are taken away, with, however, this difference in the result:—if the gas, after quitting the condenser, is passed at once into the lime purifier, and the scrubber applied afterwards, nothing but ammonia will be removed by the water; but if the scrubber be employed in the first instance, then, with every atom of ammonia taken away, one of carbonic acid and sulphuretted hydrogen will follow, and hence a great economy of lime in this way arises; for the ammonia, though itself an impurity, thus becomes a purifying agent, and the liquid from the scrubber consists, not of aqueous ammonia merely, but of a solution of carbonate and hydrosulphate of ammonia. It is, however, very difficult to separate the whole of the ammonia, either free or combined with carbonic acid, by Lowe's scrubber, without the application of a very large body of water; and it has been suggested, that excessive ablution diminishes considerably the illuminating power of coal gas. This circumstance, if true—and it is far from improbable—demonstrates the necessity of limiting the action of water upon gas, and must, in some degree, interfere with the employment of an otherwise invaluable instrument of purification. The plan of Palmer is precisely similar in its effect to the scrubber of Lowe, but more costly, and, except when conducted with great care, less efficacious, as the entire success depends upon the perfection of the condensation; for, unless the condensed water be cooled down to the mean temperature of the atmosphere, little or no ammonia will combine with it; and there is, moreover, a still greater danger of injuring the light-giving power of the gas by condensed steam, than by an equal weight of cold water. This method cannot, therefore, be considered as equal to the former, more especially when coal gas, of low specific gravity, is to be purified. The mere recital of Johnson's process almost details its mode of action; and it would scarcely be necessary to say more concerning it, but for the contrast it presents to that of Laming, and the substances before alluded to. If the phosphate of lime or bone earth, mentioned as part of Johnson's mixture, be regarded as a sponge for holding the sulphuric acid which he employs, then the ammonia is taken up from the gas by simple elective affinity with the production of sulphate of ammonia; and this is, beyond doubt, a true explanation of the *modus operandi* in Johnson's case. Here, however, it will be noticed that nothing but ammonia is removed, for the carbonic acid and sulphuretted hydrogen remain unaffected; consequently this system might be employed either before or after lime purification. Now, Laming's plan differs altogether from this, and, as will readily be seen, admits of application only before lime purification. The foul coal gas from the condenser contains carbonate of ammonia in a gaseous condition; and it has just been shown, that the process of Laming depends upon the use of muriate of lime. But at the ordinary temperature of this country these two substances are incompatible with each other; and, consequently, as fast as the carbonate of ammonia is brought by the current of gas into contact with the muriate of lime, mutual decomposition ensues, and both the ammonia and carbonic acid are solidified; the former becoming converted into muriate of ammonia, and the latter into carbonate of lime, by an interchange of elements with the muriate of lime used in the process; therefore the result differs thus far from that of Johnson,—that carbonic acid as well as ammonia is taken from the gas, and consequently a saving of lime, or other purifying material, effected: of course sulphate of lime would act in the same way, though less powerfully; whereas metallic salts, in general, having more affinity, after decomposition, for sulphuretted hydrogen than for carbonic acid, will produce an economy of lime by removing the former and not the latter impurity. Such, then, is a descriptive outline of the methods actually followed at the present day for the purification of coal gas from the ammonia it contains; and although seemingly abundant enough to have exhausted the subject, yet there is still an extensive field open to improvement even here.

Amongst the large class of ammoniacal compounds known to chemists, it seems strange that no one has yet taken advantage of that interesting series which suffers decomposition by the mere application of a moderate temperature, evolving at the same time pure ammoniacal gas, and yielding, as a residue, the substance originally employed for purification. We shall enumerate but one or two substances of this kind for the purpose of illustrating our argument, leaving the whole question as open as ever to practical investigation. When phosphate of magnesia is exposed to the action of ammoniacal gas, its acid becomes divided in such a way as to produce the triple salt called ammoniaco-phosphate of magnesia; and as this is a much more insoluble substance than the simple phosphate, we have only to pass impure coal gas through a solution or aqueous mixture of the latter, to insure the precipitation of all the ammonia contained in the gas; whilst, at the same time, the compound which it has formed with the phosphate of magnesia is very easily decomposed, so as to admit of a continuous usage of the same material; for at a temperature considerably below a red heat, the triple phosphate of magnesia parts with all its ammonia, and becomes simple phosphate again, with the renewal of its primitive power as an absorber of ammoniacal vapours. But the ammonia which is expelled by heat might very easily be condensed in water, and thus originate a valuable commodity for the market. By this means there can be no doubt phosphate of magnesia might be employed over and over again in the purification of coal gas, whilst the ammonia procured from it would contain neither sulphur nor any other impurity. An iron vessel might be used for the distillation; and if too high a heat was not given to the phosphate of magnesia, its purifying action would remain unaltered; thus presenting altogether a fair opening for the investment of talent and industry. Similarly, boracic acid deserves attention, from the facility with which, even at the temperature of boiling water, it parts with the greater portion of any ammonia previously united to it, at the ordinary heat of the climate in this country. It offers, consequently, a commodious vehicle for collecting and conveying the ammonia of gas works into public use, without the risk of nuisance or loss. Many other substances possessing this double property of absorbing and giving off ammonia by a trifling change of temperature might be pointed out; but this lies beyond our province; it is the principle only which we attempt to elucidate, with a view to its practical application in some specific instance.

Presuming that the impure gas has had all its ammonia separated by proper treatment, we have now to consider in what way the carbonic acid and sulphuretted hydrogen may be most easily got rid of. Lime is the agent commonly selected, and all things duly admitted, there is a great mass of evidence in its favour,—so much so, indeed, that, until lately, it has had no competitor. At present, however, the oxide of iron is becoming a formidable rival; and therefore we propose to examine into their respective merits, which, after all, are less alike than might be supposed in two substances selected to perform one and the same operation. When properly prepared and moistened, lime removes from impure coal gas both carbonic acid and sulphuretted hydrogen with extreme energy, and consequently effects thorough purification after the ammonia has been got rid of. Oxide of iron combines only with the sulphuretted hydrogen contained in the gas, and not with the carbonic acid; so that coal gas purified in this way requires subsequent application of lime, or some other material capable of combining with carbonic acid. Thus far, therefore, the advantage is much in favour of lime. But when lime has absorbed all the impurity it can attract from coal gas, or, in technical

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phrase becomes "foul," it is not only altogether useless, but, much worse than this, it is a serious nuisance, in consequence of the evolution of sulphuretted hydrogen the moment it comes in contact with atmospheric air, which arises from the action of the atmospheric carbonic acid upon the hydrosulphate of lime contained in the foul mass. Gas-lime refuse is therefore a grave inconvenience to many gas companies. Now with oxide of iron no such inconvenience is felt; for this substance in uniting with sulphuretted hydrogen produces a compound which yields no noxious or unhealthy emanations by the contact of air, but is, under such influence, simply oxidized, and in a great measure restored to its primitive power, so that it may be used over and over again, ten, twenty, or even thirty times in succession. These peculiarities give the oxide of iron a decided superiority in many situations, though up to the present moment its practical application has been extremely limited. When lime contained in a purifier has ceased to purify gas, the general impression is that it has been wholly resolved into carbonate and hydrosulphate of lime; but this is very far indeed from being the case, for even the foulest lime seldom contains less than one-fifth of all its lime free or uncombined; and gas-lime refuse is occasionally to be had so imperfectly saturated that fully one-half of the lime paid for by the gas company may be said to be thrown away. In the first place, it is not customary to examine the lime itself, so as to determine its chemical value or combining proportion, and still worse, it is not usual, secondarily, to analyze the lime refuse with a view to ascertain how much lime is passing away unacted on. As both of these desiderata may be secured without the application of any great chemical skill, we shall proceed to give a brief description of the means needed to solve the trifling problems, beginning with the lime itself. Having selected from the bulk a fair sample of lime, let this be ground to a fine powder in a clean and dry mortar; then weigh out 100 grs. of the powder, and place it in a tumbler or other suitable vessel, where it is to be repeatedly washed with a warm but not hot solution of sal ammoniac in water,—the temperature being about 80° or 90° Fahr. Great care must be taken that, in washing the lime, no solid particles are allowed to escape with the ammoniacal solution; and, as soon as it is observed that the fluid containing the sal ammoniac ceases to restore the colour of reddened litmus paper, after it has been poured upon the lime, then common water may be used to wash the remaining lime; after which it must be dried at a red heat, and then weighed;—the loss will indicate the amount of pure lime present in the 100 grs. taken. This mode of analysis depends upon the fact that lime, at the temperature indicated, decomposes muriate of ammonia and becomes soluble, but any carbonate of lime, silicate of lime, alumina, or other inactive impurity, remains undissolved, and may therefore have its quantity determined by the balance.

Foul gas-lime, or refuse, is somewhat more complex, but nevertheless far from difficult in its analysis. Having, as before, selected a fair sample, let 200 grs. be weighed out, and placed in a stoppered bottle, with an equal weight of sal ammoniac, and four ounces of water, heated, as before, to about 80° or 90°; shake the whole well together, and keep the mixture warm for twenty minutes; then filter rapidly into a stoppered retort, and wash the filter with two ounces of hot water, which are to be added to the filtered solution. Next distil over one-half of the fluid into a receiver containing 100 grs. of sulphate of copper, dissolved in water, and set the fluid remaining in the retort aside to cool. Collect the black precipitate now contained in the receiver upon a filter, and wash it well with hot water, then dry and weigh it: it is the sulphuret of copper, and contains one-third of its weight of pure sulphur. The fluid in the retort must now be mixed with an excess of carbonate of soda, and the white precipitate which ensues well washed, dried, and then weighed. One hundred grains of this precipitate, which is carbonate of lime, indicate 56 grs. of pure lime; and if from this we deduct the quantity combined with sulphuretted hydrogen, as given by the sulphuret of copper, the remainder will be the total quantity of pure lime in the 200 grs. of gas-lime refuse, which had not been utilized in the purifier. Thus, suppose that 200 grs. of any sample in question have given 24 grs. of sulphuret of copper, and 80 of carbonate of lime, then the total amount of lime will be 44·8 grs., from which 14 grs. must be deducted for that united to sulphuretted hydrogen, since the atom of sulphur is to that of lime as 16 to 28, and 24 grs. of sulphuret of copper contain 8 grs., or one-third of its weight of copper, which is consequently equal to 14 grs. of pure lime. This supposed sample has therefore given 30·8 grs., or 15·4 per cent. of free lime. Thus, in place of the mere rule of thumb system, too commonly pursued in gas works, a good gas engineer will control the entire produce of his manufactory by determining, first, the total amount of sulphur given off in a gaseous form by the coal he uses; next the chemical power of his lime; and lastly, whether or not the action and arrangement of the purifying apparatus is such as to insure the proper saturation of the lime with the impure constituents of the coal gas. Without the occasional employment of analytical processes, similar to those previously given, it is altogether impossible to conduct gas-works with that certainty and confidence essential to perfect economy.

It might be supposed that with the purification of coal gas the chief difficulties of a gas engineer ended, but this is very wide of the truth; for upon no point is there greater diversity of opinion, and more discrepancy in result, than exists regarding the proper mode of burning gas for the purposes of illumination and heating. As regards the former question, it seems hitherto to have been impossible of solution, from the fact that quantity and intensity of light have been confounded together; and persons have been surprised to find that a bright white light, of great intensity to the eye, has, nevertheless, illuminated a given space worse than a large quantity of dull, yellow, smoky-looking light. Thus, if when an argand oil lamp is burning with great brilliancy the central aperture for the admission of air be closed, the flame will immediately become yellow and smoky, yet, on examining the walls of the apartment, it will be found that they are better illuminated than with the more brilliant light. In the former case, many of the particles of carbon are consumed before they take on the solid condition, whereas in the latter, they are all separated from the hydrogen of the oil, and become red-hot solid bodies ere they inter into combustion. But as the quantity of light is proportioned to the number of solid particles heated, and its intensity to the elevation of the temperature to which they are heated, it follows, that part of the carbon is employed in producing heat, to give intensity of light to the remainder, in the one case, whilst in the other, the whole of the carbon becoming solid reflects a great quantity of light of less intensity. For the ordinary wants of society, the latter is the best light. A knowledge of these matters enables us easily enough to explain the vast difference in illuminating power which one and the same gas displays when consumed in different burners. Thus, a thin gas, of low specific gravity, which affords an excellent light in an argand burner, will scarcely yield any light at all with a fish-tail or bat's-wing; and a rich cannel coal gas, well adapted to either of the latter burners, requires infinite care to prevent it from smoking in an argand. In determining the relative illuminating powers of different gases, it is therefore necessary to select for each gas that form of burner best suited to display its light-giving properties, and not continue the present Procrustean system of cutting down the power of the gas to an arbitrary standard of burner; the only result of which has been a series of assertions and contradictions too disgraceful for further notice. In photometrical experiments, a spermaceti candle, of a determined size, is commonly employed, and, in a rough way, answers remarkably well. But sperm, like wax and tallow, gives quantity of light, but not of an intensity equal to gas, as may be seen in a moment by contrasting the comparatively yellow flame of the one with the brilliant white light of the other. They are therefore like musical instruments tuned to a different pitch, and can never harmonize with each other. The better plan would be to select olefiant gas as a photometrical standard, since this compound is uniform in composition, and can be easily prepared at a few minutes' notice. It possesses, moreover, the advantage of being consumed in similar burners to that employed for the gas to be tested, and is under the influence of the same barometric and thermometric variations. The Bunsen photometer, as modified by Mr. A. King, of Liverpool, is, perhaps, the best instrument to employ in experiments on comparative illumination. Regarding the ultimate analysis of coal gas little need be said, as the results have no specific value or meaning. The only correct mode of analysis is by passing a known volume of the gas over oxide of copper in a tube heated red-hot, and collecting first the moisture by chloride of calcium; secondly, the carbonic acid by hydrate of lime or solution of potash, as followed in ordinary organic analyses; and, lastly, receiving the incombustible residue over water in the pneumatic receiver: from which three products, the quantity of hydrogen, carbon, and nitrogen may be deduced. The ultimate analyses of coal gas, as also the estimation of its value from the condensation of what is termed its olefiant gas, whether by chlorine, sulphuric or nitric acid, are processes of no practical value to the public, and serve only to mislead the ignorant. From the vast reduction which is now taking place in the prices of coal gas, its calorific power has become one of the most interesting questions of the day; and when the waste of fuel consequent upon lighting a common fire, with the quantity consumed after the fire is no longer wanted, are carefully inquired into, it seems very clear, that for at least 4 or 5 months of the year it is cheaper to cook by gas in London than by coal, at the existing prices of these articles. An apposite illustration of the correctness of this assertion is afforded by the warm bath of Mr. Defries, in which 45 gallons of water are heated from the temperatures of 50° to 100° Fahr. by 30 cubic feet of gas, and at a cost of only three pence. Now, to effect this at all by coal would entail an expense of at least fourpence; but to do so in the same period of time (5 minutes), would certainly entail an outlay of not less than a shilling. Of course, where the operation is to be repeated, or go on continuously, a different result would ensue; but for extemporaneous use, coal gas will always be cheaper than coal. But even this surprising economy has been exceeded by a very elegant arrangment, invented by Mr. F. I. Evans, of Westminster, in which a coil of iron tubing is so disposed, as to present an immense surface to the heating influence of the burnt gas, and thus absorb the whole of the heat. In this way, a current of cold water entering at one end of the tube flows out of the other continuously, and at any required temperature, according to the velocity of the current, and the quantity of gas consumed in a given time. For the requirements of the Humane Society, for the public hospitals and charities, a simple apparatus of this kind must find a ready application, and deserves to be better known. According to direct experiments, made with great care, Mr. Evans has found that common Newcastle coal gas, of sp. gr. ·416, has an evaporative value equal to about 22 times its weight, or, in other words, that 1 lb. of such gas will convert, theoretically, 22 lbs. of water into steam; and this accords very well with the results given by Defries with his bath, in which 30 cubic feet of gas are stated to heat 45 gallons, or 450 lbs. of water at 50°. This is equal to 15 lbs. similarly heated for each cubic foot of gas, weighing, say 206 grains, or 750 lbs. of water heated one degree by the same means. This, estimating the latent heat of steam at 960, gives 25 parts of water boiled off for every one part of gas consumed, which is very nearly three times as great as the heating power of good Newcastle coal. But practical experiments were wanting to show he real amount of water which can be boiled off by gas, as burnt in ordinary burners beneath a boiler. This deficiency has been supplied by Mr. Evans, to whom we are indebted for the following tabular statement:—One cubic foot of gas, weighing about 205 grs., and of sp. gr. ·413, boiled off four tenths of a pound of water, or 13·6 times its weight. One cubic foot, weighing about 290 grs., and of sp. gr. ·564, boiled off five tenths of a pound, or 12 times its weight. One cubic foot, weighing about 360 grs., and of sp. gr. ·700, boiled off seven-tenths of a pound, or 13·6 times its weight. Thus showing that in the case of gas, one-third at least of all the heat evolved passes off unabsorbed by the boiler. In our comments on coal we had occasion to remark that something like one-half of all the fuel consumed under steam boilers is wasted; and it now appears that fully one-third of all the gas employed in our culinary operations must be thrown away, and will continue to be so until the hand of improvement is applied in the proper quarter. There is, unquestionably, much scope for ingenuity in devising the best forms of apparatus for burning gas, and utilizing its waste heat. A very elegant little machine, which promises to elucidate some obscure points as regards the purity of gas, has lately been added to the ordinary testing chemicals of a gas engineer. This consists of a bent tube, forming, as it were, the horizontal flue of a furnace, in which the products of combustion arising from gas may be condensed, and afterwards examined with reference to their nature. Mr. A. Wright, of Westminster, is the inventor and maker of the apparatus in question, and by its means two curious facts may at almost any time be demonstrated. One of these is, that sulphuric acid is an invariable product of the combustion of coal gas; the other, that very frequently, and more especially with cannel coal gas, a substance possessing all the properties of aldehyde makes its appearance. The latter seems to be a product of imperfect combustion, and gives rise to that peculiarly offensive odour produced wherever large quantities of coal gas are burnt in a close compartment. It is commonly believed by chemists, that coal gas contains ammonia, which in burning is converted into nitrous or nitric acid; but the apparatus of Mr. Wright demonstrates at once the fallacy of this opinion, by proving that whenever gas contaminated with ammonia is consumed, the ammonia either passes off unchanged, or is simply decomposed into its elements; for carbonate of ammonia, and not nitrate, makes its appearance in the condensed products. Before quitting the subject of coal gas, it is necessary to say a few words upon the composition and use of what is called ammoniacal liquor. This fluid condenses in the hydraulic main, and flows out with the tar, from which it afterwards separates by gravitation. Its specific gravity varies, as also does its composition; but the following may be regarded as a fair average: in one gallon, of specific gravity of 1·017, there were found of sesquicarbonate of ammonia 5984 grains, hydrosulphate of ammonia 420 grains, muriate of ammonia 985 grains, with a trace of ferrocyanate and sulphocyanate of ammonia; consequently, if the small quantity of sulphuretted hydrogen existing in ammoniacal liquor be removed, as it may be by the application of the requisite proportion of carbonate of lead, an ammoniacal solution will be produced, extremely well adapted for many useful purposes in the arts, such as scouring woollens, flax, and other goods, as well as for washing in general. In all these cases, ammonia is greatly to be preferred to soda, even at the same price; but as the ammoniacal liquor of many gas works is actually thrown away, and under no circumstance sells for more than a farthing a gallon, it is discreditable to our industrial economy that this very obvious application of ammoniacal liquor should continue to be neglected; more especially as the fluid, even after being used as above indicated, is still an excellent fertilizing agent. In the Great Exhibition, there were but few illustrations of the manufactures peculiar to gas; a circumstance attributable to the risk of permitting the necessary experiments to take place, by which alone the actual value of any improvement in gas apparatus can be correctly determined. Hence, in the Crystal Palace, merely articles of established reputation were shown, which, having been long before the

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public eye, by no means represented the existing condition of this branch of manufacture. On this account, although the decision of the executive committee to exclude experimental gas apparatus seems somewhat unfortunate, yet, when the great value of the goods shown in the Exhibition is duly considered, there can be but two opinions concerning the propriety of the step. The various samples exhibited were nevertheless extremely good of their kind, both in the British and Foreign departments. In clay retorts, the best specimen was in Class 27., by Cowan & Co., of Blaydonburn, Newcastle-on-Tyne; and the next in quality stood in the Belgian portion of the Exhibition. M. Pauvels, of Paris, exhibited a very good retort also; and there were several satisfactory-looking samples from other quarters.

Coal Gas, Composition of. From the most recent investigations into the composition of coal gas, it appears extremely doubtful whether any gaseous compound exists in it to which the name olefiant gas can, with propriety, be accorded, and it certainly seems to have been assumed on very hasty and unfounded data, that to the presence of olefiant gas the illuminating force of common coal gas is chiefly due. Without pretending to deny altogether the presence of the olefiant in the gas of our streets, it is nevertheless susceptible of proof that the quantity which, on the most liberal computation, can be allowed, is infinitely small and insignificant, and, in a practical sense, warrants the now prevailing opinion that there is really none. In support of this, it can be shown that if common coal gas be made to traverse very slowly a great length of tube exposed to the refrigerating effect of a bath of ice and salt, the gas will issue from the other end of the tube almost entirely deprived of its illuminating power; and a similar result may be obtained at ordinary temperatures by passing the gas through alcohol and other reagents. In the case of alcohol, the effect is, however, very instructive, for the alcohol gains exactly that which the gas loses in illuminating power, and, after the experiment, it is found to burn with a bright white flame, and to become milky with water. Now, on the supposition that the photogenic power of coal gas was due to olefiant, none of these results should follow, for no such cold would liquefy olefiant gas, nor would alcohol absorb it in any great degree. Moreover, all attempts to obtain, through the agency of fuming sulphuric acid, any compound like sulpho-vinic acid have utterly failed, even when tried upon a rather large scale. Hence, in regarding coal gas, it is theoretically more correct to consider its luminosity, as arising from the presence of various volatile hydrocarbons or naphthas, rather than from any permanently elastic fluid whatever. This view of the case has latterly become very prevalent, and is now leading to the most important improvements in the manufacture of illuminating gas. It has long been known that ordinary bituminous coals will yield a much larger volume of gas than may, with propriety, as regards the photogenic power of that gas, be taken away from the coal. This arises from the circumstance, that the first portions of gas are much richer in hydrocarbons than the remainder of the charge, and a period arrives at which the gas, though still great in quantity and eminently combustible, ceases to possess any value whatever as an illuminating agent. Moreover, it is known that the mixed gas obtained by decomposing water through the agency of carbon at a red heat is also combustible, but devoid of photogenic power; and it is owing to a correct appreciating of the circumstances upon which the value of common coal gas depends, that both these and other forms of combustible gas have lately been rendered as permanently luminous and well-adapted for the production of light as the best kinds of common coal gas. Having once clearly comprehended the cause of luminosity in ordinary gas, but few steps are required to perceive that the latter portion of a charge of coal, when distilling in a retort, needs but a part of the surplus hydrocarbons of the first portion to render it equally valuable, and we are insensibly drawn to the means of effecting the desired end. Thus, if the latter portions of the charge be stored away separately, and passed in regular quantities over coal which is undergoing the primary action of destructive distillation, it is clear that such gas will become charged with the hydrocarbons of that primary distillation, and thus, in all respects, resemble the first part of the charge, or, in other words, be made equal to the best gas; at the same time the amount of labour and expense incurred in condensing out these surplus hydrocarbons must be much diminished by the presence of an amount of gas capable of retaining them permanently in solution at ordinary temperatures. Not only, therefore, is it possible to procure in this way a much larger quantity of gas of an average illuminating power from a given weight of coal, but the expense of this production is decreased by the diminished condensation needed for the whole, as compared with that required for a part of the gas under the old system. But there is a still greater advantage than these, and one scarcely to have been expected. These poor gases consist chiefly of hydrogen gas, and it has been discovered that this gas possesses the remarkable property of preventing the decomposition of every form of hydrocarbon at a red heat. The consequence, therefore, of passing such gas over coals, in its primary state of distillation, is to prevent the decomposition of the various naphthas by the heat employed, and which, without the presence of hydrogen, would be resolved into solid carbon and light carburetted hydrogen, the former of which

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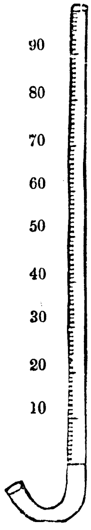
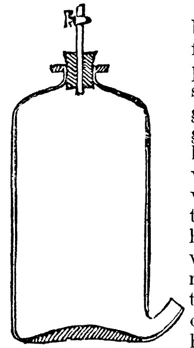
remaining in the retort impairs the utility of that vessel, whilst the illuminating power of the gas produced is greatly diminished by the loss of solid matter. Now it has been stated that to these naphthas the luminosity of gas is to be attributed, and therefore their preservation in the way described, by the action of hydrogen, would of itself be an immense step in advance of our former practice; but when to this is added the fact that, with a vastly increased preservation of hydrocarbon, there is also a vastly increased production of combustible gas to render that hydrocarbon available for public use, the real merit of the new discoveries in gas-making must strike even the most thoughtless observer. Of course, the same argument which applies to the use of the residuary gas from a charge of coal, is equally fitted to illustrate the beneficial operation of the gases evolved by decomposing water with red hot carbon. In this latter instance, however, an important fact presents itself, for unless the whole of the surplus watery vapour has been removed or condensed from this water gas, the hydrocarbons arising from the incipient distillation of the coal are destroyed, and, therefore, the object sought to be gained is lost. This accounts perfectly for the innumerable failures which have taken place in attempting to employ steam and water gas for the purpose of illumination; nor, until this subject was investigated by Mr. T. G. Barlow, does any one appear to have formed a correct opinion of the cause of such invariable want of success. Mr. Barlow, however, not only discovered the peculiar preservative power of hydrogen, but also the no less remarkably destructive action of steam, and hence, by merely condensing this latter, he has been enabled to employ water gas with a success which bids fair to prove a very profitable manufacturing speculation, and for the details of which he has secured her Majesty's letters patent in conjunction with Mr. Gore. For the application of the residuary gas from common coal to the preservation of the hydrocarbons arising from fixed oils and fats during distillation, and for the production from coals, lignite, tar, &c., of a larger amount of illuminating gas than can be obtained by the ordinary process, the public is indebted to Messrs. G. Lowe and F. I. Evans, both well known as engineers in the service of the Chartered Gas Company. That these improvements will, in some measure, revolutionise the manufacture of gas seems pretty obvious.

To determine with any degree of precision the value of a gas as an illuminating agent is really a very difficult, though seemingly a very simple affair. The most general method is by the instrument called the Bunsen photometer. The indications of this instrument (at best but imperfect) have been so largely improved by the ingenious modifications made in its use by Mr. Alfred King, of Liverpool, that it has come to occupy a position in the public confidence, to which in its original condition it had not the slightest title. The great difficulty to overcome was the securing of one uniform standard of illumination, without which, as a matter of course, the indications of the photometer were utterly valueless. This indispensable condition has been in a great meusure arrived at by Mr. King, who employs a spermaceti candle, and ascertains the amount of spermaceti actually consumed during the experiment, and then reduces this to one uniform rate of 120 grains of spermaceti burnt per hour as contrasted with an hour's consumption of the gas to be tried at the rate of five feet per hour, or in a series of ratios, from 2 to 5 feet per hour; there are, however, many disturbing causes in the burning both of the candle and of the gas, and a very serious one results from the fact that the shape of the flame of the gas materially affects its photogenic meter, thus the flat side of a bat's-wing burner will give almost one-third more light than the edge of the same burner, though the rate of consumption be unaltered.

It is necessary, therefore, to adopt some other means of determining the value of a gas than by photometry, and it would appear that this may be effected by the agency of bromine. This substance possesses in a singular degree the power of removing from coal gas the whole of the vapours upon which its luminosity depends, and if these vapours were uniform in composition, all that need be done would be to determine their volume per cent. But this is quite useless, for the vapours differ in themselves to an incredible extent, and therefore it is not only the volume, but the specific gravity of these vapours also, which must be obtained, or in other words, their total weight, for this weight represents the value of the gas. Now if we take a tube bent, closed at one end, and graduated, as shown in the following figure, we possess at once an instrument for determining the value of a gas by volume.



This tube must be filled in the first place with water, and so much of the gas passed up into it as will occupy the graduated portion, when the residuary water will act as a valve. Having placed the whole for a few minutes in a cylindrical vessel containing water, so as to secure a uniform temperature, the tube must be raised to the water level, and the exact quantity of gas recorded. When this has been done, a few drops of bromine, in all about the size of a pea, are to be dropped through the water in the tube, and a stopper or cork applied; the whole must then be well agitated, until the gas becomes tinged with the red hue of the bromine, after which the stopper must be removed under water, and a few drops of a strong solution of potash being added the stopper is to be replaced, and the whole again agitated until the bromine tint of the gas has disappeared, when the stopper must be again withdrawn under water, and the tube placed as at first in a vessel of water to regain its original temperature, when the water-level must be once more made, and the amount of absorption read off and recorded. This operation does not last more than 10 or 15 minutes, the barometer need not therefore be consulted. Precisely similar to this, but on a larger scale, is the first part of the operation for determining the weight of the condensed portion. In this case a vessel shaped as below is necessary.



This, as is evident, differs very slightly from the tube, the bottom being provided with the same water-joint contrivance for the introduction of the bromine, whilst the stopper is pierced by a hole, in which a stop-cock is very carefully fixed, so that after the action of the bromine and caustic potash, the gas may be removed by an exhausted flask so that its specific gravity can be readily determined. Before doing this, it is however advisable to wash the gas two or three times with cold water, which is easily done if we introduce the bottle into a vessel of warm water so as to expand the gas, and thus expel the fluid through the water-joint tube, which being effected, we have only to close this opening and immerse the bottle in cold water, when, by withdrawing the stopper joint, cold water will rush in, and this may be repeated at pleasure, the object being to wash the residuary or incondensable gas thoroughly; this operation requires but a short time, and if we have taken beforehand the specific gravity of the original gas, the amount of its condensation, and now know the specific gravity of the incondensable portion, it is clear that we possess the means of knowing the exact weight of that which has been condensed. Thus, a cannel coal gas at Westminster was analyzed in this way, its illuminating power by the photometer being 20 candles per 5 feet. This gas had a specific gravity of ·48500, and a condensation of 9 per cent., whilst the specific gravity of the uncondensed portion was ·336. But if 100 weigh ·33600, then 91, the amount of uncondensed, must weigh ·30576, and this deducted from ·48500, leaves ·19924 for the condensed gas, which, as we have seen, is equal to 9·5 per cent., and bringing this to the uniform standard of 100 measures, we have 2·09 for the specific gravity of this condensed vapour; and if this specific gravity be multiplied by the amount of condensation, we shall have the true value of the gas in numbers, which, by a singular coincidence, run very close with the indications of the photometer as chosen by Mr. King, that is to say, the number of spermaceti candles burning 120 grains per hour, which the gas is equal to when consumed at the rate of 5 feet per hour. In this instance that number, it will be remembered, was 20, and 2·09, the specific gravity of the condensed gas, multiplied by 9·5, its per centage absorption by bromine, gives 20·855, a very close approximation. A vast number of experiments have been made, all of which are equally conclusive as to the value of these indicators.

Coals (*heating powers of*). An accurate, systematic, and intelligible report upon the calorific properties of coal has long been needed by the manufacturing and mercantile interests of this country. In addition to the vast importance of such an inquiry, it would be perhaps impossible to point out a subject on which less difference of opinion exists as to the extent and nature of the information wanted than the one before us. Science, properly speaking, has little or nothing to do with the question; the object in view is purely and exclusively practical, and is meant for the guidance of practical men and for practical purposes. Theory, above all things, should be carefully avoided in such investigations; and supremely indifferent about the assistance of any eminent chemist on such an occasion, we should, nevertheless, insist strongly upon the necessity of providing a good stoker. Mr. Hume, M. P., however thought otherwise; and to him the country is indebted for the first report upon the coals destined for the steam navy. Of this report we will venture to say at once that a more garbled, more inaccurate, and less impartial job was never exhibited—nay, not even in the House of Commons. To begin at the beginning of this disgraceful affair, we will merely remark that Mr. Hume (whose honesty and integrity are beyond suspicion) directed the attention of the Lords of the Admiralty to a subject which, if these Lords attended to anything but their salaries, must have occupied their attention years ago. Mr. Hume, after referring their lordships to an American report, with experiments, on the evaporative value of coals, says:—

"They have decided by direct and practical tests the comparative usefulness of American and English coals, as well as the relative value of the former in their numerous varieties; and I submit to your lordships that a similar inquiry should be instituted into the comparative usefulness of English, Scotch, and Irish coals, with the view of ascertaining the best for the naval steamers of this country. I may be allowed to point out to your lordships that there is a public establishment in Craig's-court perfectly qualified to apply the requisite direct and positive tests to the coals without delay; and to that establishment may be added one chemist of eminence to assist in what is an object of great national importance."

Upon this the Admiralty applied to Sir H. de la Beche, who, after the usual preliminary remarks, observes:—

"As the funds of the Museum of Economic Geology are, unaided, inadequate to an investigation of this order, I would suggest that the Admiralty be requested to furnish aid to the amount of 600*l.* for the remainder of the year ending the 31st of March, 1846. With this aid I have little doubt that we should be enabled to accomplish much this year which may be of value, and have organized a system of inquiry alike effective, and, viewing its national importance, which can be carried out at comparatively small cost to the public."

We must content ourselves by guessing at the meaning of the last paragraph, and, as far as this can be done with safety, we may conclude that, in the opinion of Sir H. de la Beche, the funds of the Economic, plus 600*l.*, would answer the object in view, to wit, the obtaining a practical report upon the evaporative power of English, Scotch, and Irish coals. If anything else is meant, why is 600*l.* named? The question is very fairly put by Lord Lincoln, who, in reference to the establishment in Craig's-court, asks, in plain English, "What is the course you would recommend for making it effective for the purposes to which such an inquiry would be obviously directed?" Sir H. de la Beche in answer mentions 600*l.* in addition to the funds of the Museum of Economic Geology; yet something more appears to have been given by the following "memorandum":—

"The Admiralty having acceded to the recommendation made in the foregoing letter, and subsequently also supplied additional funds for the investigation, the latter was commenced as soon as the needful apparatus was erected and proper assistance procured, which could not be accomplished until March, 1846."

Now, what is the meaning of the additional funds supplied for the investigation? Were the funds of the Economic, plus 600*l.*, spent on apparatus alone? And was it to the mere erection of this apparatus that Sir H. de la Beche alluded when, in 1845, he wrote, "With this aid I have little doubt that we should be enabled to accomplish *much* this year," &c.?

There is a mystery about the very commencement of that business. Seldom do we find Government officials ready to comply with the prayer of a petition which has merely public utility to recommend it; but Mr. Hume has nothing to complain of on that score in the present instance, for in addition to the Craig's-court establishment he solicited but one chemist, when lo! the investigation falls into the hands of Dr. Lyon Playfair, Mr. Wilson, Mr. J. Arthur Phillips, Mr. Kingsbury, Mr. Wrightson, Mr. Galloway, Mr. Hoy,. and William Hutchinson, all and each endowed with qualifications of a peculiar and important character bearing upon the investigation in hand, and tending of course to render the report superlatively correct, useful, impartial, &c., &c. There is an old axiom regarding broth made by a multiplicity of cooks, but perhaps it does not apply to parliamentary reports and chemists.

The mystery does not, however, end here. Mr. Hume had requested that the inquiry should be made upon English, Scotch, and Irish coals. Now, the following is the list of coals operated on:—

NAMES OF COALS EMPLOYED IN THE EXPERIMENTS.

WELSH—

Graigola,
Anthracite, Jones and Co.
Old Castle Fiery Vein,
Ward's Fiery Vein,
Binea,
Llangenneck,
Pontrepoth,
Pontrefellin,
Duffryn,
Mynydd Newydd,
Three Quarter Rock Vein,
Cwm Frood Rock Vein,
Cwm Nanty Gros,
Resolven,
Pontypool,
Bedwas,
Ebbw Vale,
Porth Mawr,
Coleshill.

Scotch—

Dalkeith Jewel Seam,
Dalkeith Coronation Seam
Wallsend Elgin.
Fordel Splint,
Grangemouth.

English—

Broomhill,
Lydney (Forest of Dean).

Irish—

Slievardagh Irish Anthracite.

From which it appears that the inquiry has been made almost exclusively upon Welsh coals, for, out of twenty-seven samples of coal examined,

19 were Welsh,
5 „ Scotch,
2 „ English,
1 was Irish.

One of two things is very plainly exhibited by this table; either Wales is, above all other places in the world, blessed with coals "suited to the steam navy," or a most unjust and uncalled-for selection has been made for private purposes. It is vain to talk of a next report; it will require years to complete another report, even if such another disgraceful exhibition of partiality was attempted; and meanwhile our steam navy must be supplied with the euphonious productions of Wales, to the exclusion of the vast coalfields of Newcastle. Of the two samples of English coal examined I am practically acquainted with but one, for of the Lydney coal I know nothing; as regards the Broomhill coal, however, I can safely assert that its only recommendation consists in its belonging to Earl Grey, for at Newcastle it is regarded as an unimportant second-rate coal, the very name of which has not yet found its way into the London market. It is far inferior for steam purposes to the whole of the undermentioned coals, many of which are, in fact, the best steam coals for sea-going vessels in the kingdom:—

Carr's Hartley,
Hasting's Hartley,
Hedley's Hartley,
Newcastle Hartley,
Percy North Hartley,
Richardson's Hartley,
West Hartley,
Bate's West Hartley,
Buddle's West Hartley,
Davidson's West Hartley,
Nelson's West Hartley.

Why these and many others have been passed over so unceremoniously to make room for the wholesale introduction of the Welsh coal remains to be explained; we will now, however, examine the report itself.

The first circumstance which attracts attention in this report is the appearance of certain very simple equations, which, although well enough adapted for a boy just commencing algebra, are singularly out of place here, since those who understand such things generally prefer to make their own equations; and those who do not are but little likely to benefit by such a display of learning.

A curious attempt is made at page 13. to prove that the evaporative value of a bituminous coal is expressed by the evaporative value of its coke:—

"It is easy," says the report, "from analysis to examine whether the duty performed by the coal is to be attributed to its fixed ingredients or coke, by estimating the work which the latter is capable of performing. This may be done by subtracting the ashes in the coal from its amount of coke, and estimating the remainder as carbon; this carbon multiplied by its heating power, 13268, and divided by 965·7, or the latent heat of steam, indicates the number of pounds of water which the coke by itself could evaporate without the aid of the combustible ingredients of the coal. These results are placed in column 3. of Table 6. (see next page), in juxtaposition with the actual work done by the coal, and it will be seen that, notwithstanding several striking exceptions, which might have been expected, they on the whole show that the work capable of being performed by the coke alone is actually greater than that obtained by experiments with the original coal."

Now, if this table proves anything, it proves the very reverse of the position attempted to be established, unless theory is presumed to be equal to practice, which it certainly is not, or why the necessity of spending upwards of 600*l.* in practical experiments? But theory may be justly compared with theory, and then the table, so far from proving "that the evaporative value of a bituminous coal is expressed by the evaporative value of its coke," clearly proves that the evaporative power of a bituminous coal is an immense deal greater than that of its coke; indeed almost double; and that the volatile ingredients of coal evolve in burning relatively a much greater proportion of heat than the fixed constituents; this is, indeed, precisely what might have been expected from the well-known caloric power of hydrogen, which is three times greater than that of carbon. There is, however, clearly a design throughout this report to extol the anthracite coals at the expense of the bituminous; and, if Messrs. de la Beche and Co. could succeed in establishing the fact that the heating power of coal is due solely or even principally to its relative amount of carbon, it follows that Welsh coal must rise in the market, for the greater part of the coal from that district is of the anthracite kind, none of which is worked in the north of England. To prove the absurdity, however, of the above attempt, I will quote two or three cases from Table No. 6.:—

EXTRACT FROM TABLE 6., SHOWING THE ACTUAL DUTY AND THAT WHICH IS THEORETICALLY POSSIBLE OF THE COALS EXAMINED.

Name or Locality of Coal.	Actual Number of lbs. of Water converted into Steam by 1lb. of Coal. Practical.	Number of lbs. of Water converted into Steam by the Coke left by the Coal. Theoretical.	Total Number of lbs. of Water convertible into Steam by 1lb. of the Coal. Theoretical.	Amount of Ammonia corresponding to the Nitrogen contained in the Coal.	Amount of Sulphate of Ammonia corresponding to the Nitrogen contained in the Coal.
Graigola - - -	9·35	11·301	13·563	0·497	1·932
Anthracite, Jones and Co. -	9·46	12·554	14·593	0·225	0·990
Old Castle Fiery Vein -	8·94	10·601	14·936	1·590	6·175
Ward's Fiery Vein - -	9·40	- -	14·614	1·238	4·808
Binea - - - - -	9·94	11·560	15·093	1·586	6·741
Llangenneck - - -	8·86	10·599	14·260	1·299	5·044
Pontrepoth - - - -	8·72	10·873	14·838	0·218	0·848
Pontrefellin - -	6·36	10·841	13·787	a trace	—
Powell's Duffryn - -	10·149	11·134	15·092	1·76	6·835
Mynydd Newydd - -	9·52	9·831	14·904	1·808	7·340
Three Quarter Rock Vein -	8·84	7·081	13·106	1·299	5·044
Cwm Frood Rock Vein -	8·70	8·628	14·788	1·347	5·232
Cwm Nanty Gros - -	8·42	8·243	13·932	1·919	7·448
Resolven - - -	9·53	10·234	13·971	1·675	6·505
Poutypool - - - -	7·47	8·144	14·295	1·639	6·364
Bedwas - - -	9·79	8·897	14·841	1·748	6·788
Ebbw Vale - - -	10·21	10·441	15·635	2·622	10·182
Porth Mawr Rock Vein -	7·53	6·647	12·811	1·554	6·033
Coleshill - - - -	8·0	6·468	12·799	1.785	6·930
Dalkeith Jewel Seam -	7·08	6·239	12·313	1·214	0·471
Dalkeith Coronation - -	7·71	6·924	12·772	a trace	—
Wallsend Elgin - - -	8·46	6·560	13·422	1·712	6·647
Fordel Splint - - -	7·56	6.560	13·817	1·372	5·327
Grangemouth - - -	7·40	7·292	13·692	1·639	6·364
Broomhill - - - -	7·30	7·711	14·863	2·234	8·674
Park End Lydney - -	8·52	6·567	13·257	1·477	9·617
Slievardagh - - -	9·85	10·895	12·482	0·279	1·084

Name of the Coal.	Theoretical Weight of Water Evaporated		Excess due to Volatile Ingredients.	
	by Coke.	by Coal.		
Welsh—				
Graigola - - - -	11·301	13·563	2·262	The thing speaks for itself.
Old Castle Fiery Vein -	10·601	14·936	4·335	
Mynydd Newydd - -	9·831	14·904	5·073	
Scotch—				
Dalkeith Jewel Seam -	6·239	12·313	6·074	
English—				
Broomhill - - -	7·711	14·863	7·152	

After theoretically demonstrating that "the evaporative value of a bituminous coal is expressed by the evaporative value of its coke, the heat of combustion of its volatile products proving in practice little more than that necessary to volatilize them," we are suddenly greeted with the following paragraph:—

"The whole system of manufacturing coke is at present very imperfect. Besides losing the volatile combustible substances, which, under new adjustments, might be made of much value, an immense quantity of ammonia is lost by being thrown into the atmosphere. Ammonia and its salts are daily becoming more valuable to agriculture, and it is their comparative high price alone which prevents their universal use to all kinds of cereal cultivations. By a construction of the most simple kind the coke-ovens now in use might be made to economize much of the nitrogen, which invariably escapes in the form of ammonia. As an inducement to this economy, we have ap-

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pended to Table 6. two columns showing the quantity of ammonia and its corresponding quantity of commercial sulphate which each 100 lbs. of the respective coals may be made to produce. When it is remembered that the price of sulphate of ammonia is about 13*l.* per ton, or that 100 tons (of coal, we suppose) in coking is (are?) capable of producing on an average about six tons of this salt, its neglect is highly reprehensible."

Nothing has tended half so much to retard the cultivation of chemistry by our practical manufacturers as the kind of statements of which the above is a sample. Written by individuals wholly ignorant of the subject of which they treat, these assertions serve only to amuse practical men, and to demonstrate the stupendous folly and assurance of their authors. Imperfection is an attribute of humanity, but that the present system of making coke is very imperfect remains to be proved.

The volatile combustible matter of the coal is not lost; on the contrary, it is employed as a means of converting the cinder of the coal into coke, and that, too, by the heat which it evolves in burning; and if that heat was so inconsiderable as the report would lead us to suppose, mere cinder alone would remain in the coke-oven, even after the heat had been kept up for ninety-six hours. Perhaps the framers of the report may want to know the distinction between cinders and coke. Coke, if good, sinks in water; bad coke or cinder swims. The reason of this is very simple. The longer and higher the heat to which carbon from wood or coal is exposed the more it contracts, and consequently the denser it becomes. The volatile combustible matter of the coal is employed, then, in producing the requisite temperature for coking, and the oven is so contrived as to retain the heat a sufficient time to produce the necessary aggregation of the particles of carbon, or, in plain words, the condensation of the coke: to assert that this volatile combustible matter is lost is perfectly ridiculous. We are next informed that "an immense quantity of ammonia is lost by being thrown into the atmosphere," and that by "a construction of the most simple kind this loss might be avoided." Lord Dundonald, about fifty years ago, had the same idea, and tried it on a large scale; it is unnecessary to say that it proved to be a complete failure, although sulphate of ammonia was then worth four or five times its present price. But the most absurd part of this scientific soap-bubble is contained in the last sentence:—"100 tons in coking is capable of producing on an average about six tons of this salt" (sulphate of ammonia). Now, let us for a few minutes imagine my Lord Grey desirous as (we have no doubt he is) of making the most of his Broomhill coal. Passing his eye down column 1. of Table 6., he sees at a glance that 100 tons of coal will produce 8·674 tons of sulphate of ammonia, worth 13*l.* per ton. Making a little allowance for loss, he says to himself, "Well, call it 8½ tons; and now how much sulphuric acid is required?" We will suppose him practically acquainted with Dr. Wollaston's scale, and that, valuing common "chamber acid" at three farthings per cent., he has arrived at the following conclusion:—

	l.	*s.*	*d.*
100 tons of coal, at 3*s.* 4*d.* per ton =	16	13	4
6½ tons of sulphuric acid, as above =	45	10	0
	62	3	4

will produce

	l.	*s.*	*d.*
8½ tons of sulphate of ammonia, worth	110	10	0
and 70 tons of coke, at 8*s.* 6*d.* per ton	29	15	0
	140	5	0

A promising speculation truly, if his lordship could only economize "the nitrogen which *invariably* escapes in the form of ammonia." But, most unfortunately, the nitrogen does not "invariably escape in the form of ammonia," for in practice nine-tenths of it invariably escape in the form of nitrogen, as any experienced gas manufacturer can testify, and as the experiments quoted in the report abundantly prove, for according to Mr. F. C. Wrightson (a pupil of Liebig), who (*vide* Report, page 6.) had fitted "himself by special study for an undertaking requiring so much delicacy of manipulation,"—according, then, to Mr. Wrightson (page 58.), the Binea coal and the Llangenneck coal gave by actual experiment in 100 parts 0·08 of ammonia, or ·310 of sulphate of ammonia. Now, if we compare this with Table 6. we shall find—

Binea coal	might, could, would, or should produce	6·741	really did produce	0·310
Llangenneck		5·044		0·310

or about $\frac{1}{20}$th of the quantity theoretically obtained by Sir H. De la Beche and Dr. Lyon

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Playfair; yet these are the individuals who find fault with our manufacturers, and pretend to improve our processes. With quite as much practical utility might these gentlemen have detailed to us the quantity of pure diamond which the coals in question would produce, if we knew how; as the amount of ammonia which they might give off if they would. Of the analytical part of the report we will say little more than that it is in perfect keeping with the rest. In the first place, chloride of calcium is employed to remove water and ammonia from the gas, although a very little practical knowledge of gas purification would have taught the operator that, when water and ammonia are absorbed by chloride of calcium, carbonic acid is also taken up, so as to produce carbonate of lime and muriate of ammonia; and as this carbonic acid must have been regarded either as ammonia or water, it follows that the experimental results are valueless. The substance which ought to have been employed to absorb water and ammonia under the circumstances is the fused or glacial phosphoric acid; but what real value can we attach to experiments made upon less than half a grain of coal, in which the errors, and errors there are, have been multiplied at least 300,000 times? For example, at page 58., we find "Anthracite, from T. Aubrey and Co." The quantity of this coal taken for analysis was 0·2763 of a grain, or rather more than ¼ of a grain. Now, supposing it had even equalled ⅓ of a grain, then to bring this to a pound it must be multiplied 21,000 times, and to raise this last to the weight of water which 1 lb. of such coal could theoretically evaporate, as represented at column 4. of Table 6., this 21,000 must be multiplied by 14·593; therefore, if any error occurred in the analysis of this anthracite coal, it has been multiplied upwards of 306,453 times; in regard to the quantity of water which 1 lb. of such coal can evaporate, as exhibited in column 4. of Table 6. The idea, however, of weighing the $\frac{1}{10000}$th of a grain is perfectly new to us, who have always regarded even the $\frac{1}{1000}$th as something too nearly approaching the imponderable. These remarks apply equally to the experiments with litharge; no allowance is made, or notice taken of the error arising from the presence of iron pyrites in the coal, although this substance would reduce more than 9 times its weight of litharge, and the error thus produced has been multiplied upwards of 90,000 times in column 6. of Table 4.; and in the case of the anthracite coal above mentioned this error has been increased 104,507 times. Nor is the quantity of iron pyrites inconsiderable in many of these coals, for, according to Table 3., the following contain a portion of sulphur equivalent to bisulphuret of iron, as under:—

Slievardagh - - - -	12·67 per cwt.	of iron pyrites for which no allowance has been made in the litharge experiments.
Resolven - - - -	9·50 „	
Bedwas - - - -	6·56 „	
Cwm Nanty Gros - - -	5·64 „	

To pretend to attach any value to such experiments, or to the conclusions drawn from them, is a mere fallacy, and, as the whole of the theoretical part is based upon these analyses, with them it must fall to the ground as erroneous and illusory. Under these circumstances it becomes necessary to inquire most carefully into the large and practical essays made for the purpose of determining the quantity of water evaporated during many successive hours by considerable quantities of each particular coal. With a few exceptions, each coal was burnt for eight hours, and the experiment repeated three times, the quantity of coal consumed and of water evaporated being noted in each instance, and an average drawn from the three results obtained by each coal. If carefully conducted, this method ought to have furnished some valuable information, but the discrepancies in respect to the three results obtained from some of the coals are so enormous and unaccountable as to render the whole table suspicious, doubtful, and therefore valueless; indeed, the differences observable between many of the different samples of coal are much less than the experimental differences given by one and the same coal, and which occasionally amount to little short of twenty per cent., as the following table will show [see p. 446.].

The idea of forming a table from experiments producing such discordant results is altogether preposterous, yet, turn in what direction we may, the same evidence of blundering and incapacity presents itself. In the first place, the selection of the coals was bad and unfair in the extreme, and no way calculated to answer the practical end in view; secondly, the proximate analyses are worthless, from the employment of chloride of calcium for a purpose for which it was not adapted; thirdly, the ultimate analyses are made in quantities too small to entitle them to any confidence when their results are raised to practical purposes; fourthly, the litharge experiments are erroneous; and fifthly, the practical essays by means of the Admiralty boiler are so completely at variance amongst themselves as to defy all arrangement or computation.

The entire report is, in fact, a disgrace to the age and country we live in, and carries with it all the internal evidence of a job.

As it is possible, however, that the Admiralty may really be serious in its desire to ascertain the true value of steam-coal, we will venture to throw out a few hints, in order

Name of Coal.	Extreme Difference in Three Trials as to the Amount of Water evaporated by each respective Coal
Duffryn - - - - -	2·3 per cent.
Old Castle - - -	11· "
Ward's - - - - -	5·3 "
Binea - - - - - -	14·7 "
Llangenneck - - - -	16· "
Mynydd - - - - -	4·9 "
Three Quarter - - -	1·4 "
Graigola - - - - -	2·1 "
Lydney - - - - - -	11·8 "
Pontrepoth - - - -	9·1 "
Cwm Frood - - - -	1·3 "
Anthracite - - - -	5·6 "
Cwm Nanty Gros - - -	4·8 "
Grangemouth - - - -	6·7 "
Broomhill - - - - -	5·2 "
Resolven - - - - -	18·9 "
Pontypool - - - - -	17·7 "
Bedwas - - - - - -	13·4 "
Porth Mawr - - - -	9·5 "
Ebbw Vale - - - -	15·7 "
Fordel Splint - - - -	14·5 "
Coleshill - - - - -	11·5 "
Wallsend Elgin - - -	7·3 "

that that august body of well-paid functionaries may look before they leap into a subject so intimately connected with our national interests.

In working a seam of coal, experience has shown that the quality of the coal is not uniform, and that a coal may be improving or deteriorating as the workings are carried on, in one or another direction. From this it follows that any particular coal examined, say in 1846, is by no means to be regarded as possessing the same value in 1848, since this may have changed considerably, if the working of the coal has been carried on to any great extent; and it is the determination of this very fact which constitutes the real source of utility to be derived from a Government investigation. The proximate value of a coal is soon determined by actual experiment, from the amount of work done, and a market value is given in accordance with these rough results; but, when once that value has become fixed, there it remains for many years, whether the coal continues uniform or not, and it is only slowly and by degrees that the change becomes apparent. An establishment for determining matters of this kind is, therefore, much needed, but, to be useful, it must obviously be permanent. Again, as the transmission of heat from one body to another is proportional to the difference of temperature between the bodies themselves, it is clear that the water operated on should have one uniform temperature in all the experiments, and there are many reasons why this should be the boiling point. The quantity of water evaporated should not be inferred from the quantity which has escaped from a boiler during an experiment; independent of the possibility of leakage, much water is occasionally carried off mechanically by the steam; hence the origin of "**priming**" The most unobjectionable method would be to distil the water and afterwards measure it, the still-head being provided with a return-pipe, as is usual, for the fluid, mechanically projected. The ordinary modes of favouring the transmission of heat from the furnace to the boiler, and of preventing its escape in any other direction than into the refrigeratory, should be had recourse to. A chemist is of no use for such investigations; if any chemical question should arise out of the experiments, it would be better to consult some one of established reputation. The stoker should be intelligent, and practically acquainted with the different modes of fire necessary for anthracitic, open-burning, and bituminous, or caking coal; for whilst the first of these will take, nay requires, eighteen or twenty inches of fuel on the bars, the last will not bear more than four or six, without an enormous loss of heating-power. To this cause must be ascribed much of the discrepancy apparent in the experimental results obtained by the Admiralty boiler.—*Mr. Lewis Thompson, in "The Chemical Times" for December*, 1848.

COBALT. This metal being difficult to reduce from its ores, is therefore very little known, and has not hitherto been employed in its simple state in any of the arts; but its oxide has been extensively used on account of the rich blue colour which it imparts to glass, and the glazes of porcelain and stone-ware. The principal ores of cobalt are those designated by mineralogists under the names of *arsenical cobalt* and *gray cobalt*. The first contains, in addition to cobalt, some arsenic, iron, nickel, and occasionally silver, &c. The other is a compound of cobalt with iron, arsenic, sulphur, and nickel. Among the gray cobalts, the ore most esteemed for its purity is that of Tunaberg in Sweden. It is often in regular crystals, which possess the lustre and color of polished steel. The specific gravity of cobalt pyrites is 6·36 to 4·66. The Tunaberg variety afforded to Klaproth, cobalt, 44; arsenic, 55·5; sulphur, 0·5; so that it is an arseniuret. Others, however, contain much sulphur as well as iron. It imparts at the blowpipe a blue color to borax and other fluxes, and gives out arsenical fumes.

The ore being picked, to separate its concomitant stony matter, is pounded fine and passed through a sieve; and is also occasionally washed. The powder is then spread on the sole of a reverberatory furnace, the flue of which leads into a long horizontal chimney. Here it is exposed to calcination for several hours, to expel the sulphur and arsenic that may be present; the former burning away in sulphurous acid gas, the latter being condensed into the white oxyde or arsenious acid, whence chiefly the market is supplied with this article. This calcining process can never disengage the whole of these volatile ingredients, and there is therefore a point beyond which it is useless to push it; but the small quantities that remain are not injurious to the subsequent operations. The roasted ore is sifted anew; reduced to a very fine powder, and then mixed with 2 or 3 parts of very pure silicious sand, to be converted into what is called *zaffre*. With this product glasses are generally colored blue, as well as enamels and pottery glaze. In the works where cobalt ores are treated, a blue glass is prepared with the zaffre, which is well known under the name of smalt or azure blue. This azure is made by adding to the zaffre 2 or 3 parts of potash, according to its richness in cobalt, and melting the mixture in earthen crucibles. The fused mass is thrown out while hot into water; and is afterwards triturated and levigated in mills mounted for the purpose. There remains at the bottom of the earthen pot a metallic lump, which contains a little cobalt, much nickel, arsenic, iron, &c. This is called *speiss*.

As it is the *oxyde* of cobalt which has the coloring quality, the calcination serves the purpose of oxydizement, as well as of expelling the foreign matters.

A finer cobalt oxyde is procured for painting upon hard porcelain, by boiling the cobalt ore in nitric acid, which converts the arsenic into an acid, and combines it with the different metals present in the mineral. These arseniates, being unequally soluble in nitric acid, may be separated in succession by a cautious addition of carbonate of soda or potash; and the arseniate of cobalt as the most soluble remains unaffected. It has a rose color, and is easily distinguishable, whence the precipitation may be stopped at the proper point. The above solution should be much diluted, and the alkali should be cautiously added, with frequent agitation.

The cobalt ores, rich in nickel, are exposed to slow oxydizement in the air, whereby the iron, cobalt, arsenic, and sulphur get oxygenated by the atmospheric moisture, but the nickel continues in the metallic state. This action of the weather must not be extended beyond a year, otherwise the nickel becomes affected, and injures the cobalt blue. The ore hereby increases in weight, from 8 to 10 per cent. *Fig.* 362 is a longitudinal section of the furnace: *fig.* 363, a horizontal section upon a level with the sole of the hearth. It is constructed for wood fuel, and the hearth is composed of fire-bricks or tiles. The vapors and gases disengaged in the roasting pass off through the flues *a a*, into the channels *b b*, and thence by *c* into the common vent, or poison chamber. See the representation of the poison tower of Altenberg, under the article Arsenic. The flues are cleared out by means of openings left at suitable situations in the brick-work of the chimneys.

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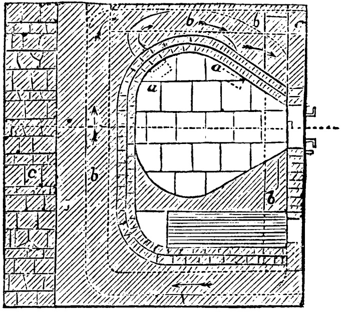

The azure manufacture is carried on chiefly in winter, in order that the external cold may favour the more complete condensation of the acids of arsenic. From 3 to 5 cwt. of Schlich (pasty ore) are roasted at one operation, and its bed is laid from 5 to 6 inches thick. After two hours, it must be turned over; and the stirring must be repeated every half hour, till no more arsenic is observed to exhale. The process being then finished, the ore must be raked out of the furnace, and another charge introduced.

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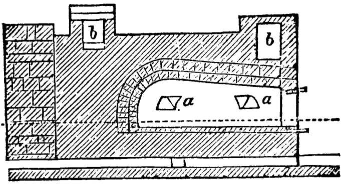

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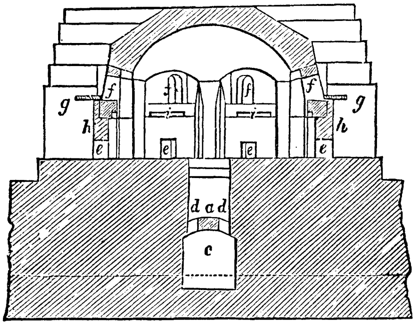

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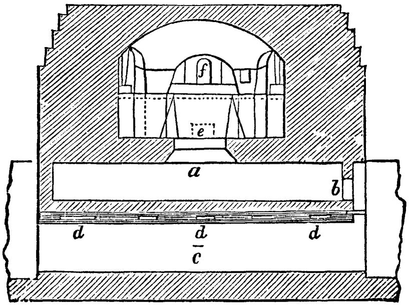

The duration of the roasting is regulated partly by the proportion of sulphur and arsenic present, and partly by the amount of nickel; which must not be suffered to become oxydized, lest it should spoil the color of the smalt. The latter ores should be but slightly roasted, so as to convert the nickel into *speiss*. The roasted ore must be sifted in a safety apparatus. The loss of weight in the roasting amounts, upon the average, to 36 per cent. The roasted ore has a brownish gray hue, and is called *safflor* in German, and is distributed into different sorts. F F S is the finest *safre;* F S, fine; O S, ordinary; and M S, middling. These varieties proceed from various mixtures of the calcined ores. The roasted ore is ground up along with sand, elatriated, and. when dry, is called *zaffre*. It is then mixed with a sufficient quantity of potash for converting the mixture into a glass.

Figs. 364 and 365, represent a round smalt furnace, in two vertical sections, at right angles to each other. The fire-place is vaulted or arched; the flame orifice *a*, is in the middle of the furnace; *b* is the feed hole; *c*, a tunnel which serves as an ash-pit, and to supply air; *d*, openings through which the air arrives at the fuel, the wood being placed upon the vault; *e*, knee holes for taking out the scoriæ from the pot bottoms; *f*, working orifices, with cast-iron plates *g*, in front of them. Under these are the additional outlets *h*. The smoke and flame pass off through the orifices *i*, which terminate in expanded flues, where the sand may be calcined or the wood may be baked. Eight hours are sufficient for one vitrifying operation, during which the glass is stirred about several times in the earthen melting pots.

The preparation of the different shades of blue glass is considered a secret in the smelting works; and marked with the following letters:—F F F C, the finest; F C, fine; M C, middling; O C, ordinary. A melting furnace, containing 8 pots of glass, produces in 24 hours, from 24 cwts. of the mixture, 19 cwts. of blue glass; and from ½ to ¾ cwt. of scoriæ or speiss (*speise*). The composition *speise*, according to Berthier, is,—nickel, 49·0; arsenic, 37·8; sulphur, 7·8; copper, 1·6; cobalt, 3·2 in 100. Nickel, arsenic, and sulphur, are its essential constituents; the rest are accidental, and often absent. The freer the cobalt ore is from foreign metals, the finer is the colour, and the deeper is the shade; paler tints are easily obtained by dilution with more glass. The presence of nickel gives a violet tone.

The production of smalt in the Prussian states amounted, in 1830, to 7452½ cwts., and in Saxony to 9697 cwts.; in 1825, to 12,310 cwts.

One process for making fine smalt has been given under the title Azure; I shall introduce another somewhat different here.

The ore of cobalt is to be reduced to very fine powder, and then roasted with much care. One part, by weight, is next to be introduced, in successive small portions, into an iron vessel, in which three parts of acid sulphate of potassa has been previously fused, at a moderate temperature. The mixture, at first fluid, soon becomes thick and firm, when the fire is to be increased, until the mass is in perfect fusion, and all white vapours have ceased. It is then to be taken out of the crucible with an iron ladle, the crucible is to be recharged with acid sulphate of potash, and the operation continued as before, until the vessel is useless. The fused mass contains sulphate of cobalt, neutral sulphate of potassa, and arseniate of iron, with a little cobalt. It is to be pulverized, and boiled in an iron vessel, with water, as long as the powder continues rough to the touch. The white, or yellowish white residue, may be allowed to separate from the solution, either by deposition or filtration. Carbonate of potassa, free from silica, is then to be added to the solution, and the carbonate of cobalt thrown down is to be separated and well washed, if possible, with warm water; the same water may be used to wash other portions of the fused mass. The filtered liquid which first passes is a saturated solution of sulphate of potassa: being evaporated to dryness in an iron vessel, it may be reconverted into acid sulphate by fusing it with one half its weight of sulphuric acid: this salt is then as useful as at first.

The oxyde of cobalt thus obtained contains no nickel; so little xyde of iron is present, that infusion of galls does not show its presence; it may contain a little copper, if that metal exists in the ore, but it is easily separated by the known methods. Sometimes sulphureted hydrogen will produce a yellow brown precipitate in the solution of the fused mass; this, however, contains no arsenic, but is either sulphuret of antimony or bismuth, or a mixture of both.

It has been found advantageous to add to the fused mass sulphate of iron, calcined to redness, and one tenth of nitre when the residue is arseniate of iron, and contains no arseniate of cobalt. There is then no occasion to act upon the residue a second time for the cobalt in it.

This process is founded on the circumstances that the sulphate of cobalt is not decomposed by a red heat, and that the arseniates of iron and cobalt are insoluble in all neutral liquids. It is quite evident, that, to obtain a perfect result, the excess of acid in the bisulphate of potassa must be completely driven off by the red heat applied.

110,646 lbs. of smalts were imported into the United Kingdom in 1835, and 96,949 were retained for home consumption. In 1834, only 16,223 lbs. were retained.

In 1835, 322,562 lbs. of zaffres were imported, and 336,824 are stated to have been retained, which is obviously an error. 284,000 lbs. were retained in 1834.

COCCULUS INDICUS, or Indian berry, is the fruit of the *Menispermum Cocculus*, a large tree, which grows upon the coasts of Malabar, Ceylon, &c. The fruit is blackish, and of the size of a large pea. It owes its narcotic and poisonous qualities to the vegeto-alkaline chemical principle called *picrotoxia*, of which it contains about one fiftieth part of its weight. It is sometimes thrown into waters to intoxicate or kill fishes; and it is said to have been employed to increase the inebriating qualities of ale or beer. Its use for this purpose is prohibited by act of parliament, under a penalty of 200*l.* upon the brewer, and 500*l.* upon the seller of the drug.

COCHINEAL was taken in Europe at first for a seed, but was proved by the observations of Lewenhoeck to be an insect, being the female of that species of shield-louse, or *coccus*, discovered in Mexico, so long ago as 1518. It is brought to us from Mexico, where the animal lives upon the *cactus opuntia* or *nopal*. Two sorts of cochineal are gathered—the wild, from the woods, called by the Spanish name *grana silvestra;* and the cultivated, or the *grana fina*, termed also *mesteque*, from the name of a Mexican province. The first is smaller, and covered with a cottony down, which increases its bulk with a matter useless in dyeing; it yields, therefore, in equal weight, much less color, and is of inferior price to that of the fine cochineal. But these disadvantages are compensated in some measure to the growers by its being reared more easily, and less expensively; partly by the effect of its down, which enables it better to resist rains and storms.

The wild cochineal, when it is bred upon the field nopal, loses in part the tenacity and quantity of its cotton, and acquires a size double of what it has on the wild opuntias. It may therefore be hoped, that it will be improved by persevering care in the rearing of it, when it will approach more and more to fine cochineal.

The fine cochineal, when well dried and well preserved, should have a gray colour, bordering on purple. The gray is owing to the powder, which naturally covers it, and of which a little adheres; so also to a waxy fat. The purple shade arises from the colour extracted by the water in which they were killed. It is wrinkled with parallel furrows across its back, which are intersected in the middle by a longitudinal one; hence, when viewed by a magnifier, or even a sharp naked eye, especially after being swollen by soaking for a little in water, it is easily distinguished from the factitious, smooth, glistening, black grains, of no value, called East India cochineal, with which it is often shamefully adulterated by certain London merchants. The genuine cochineal has the shape of an egg, bisected through its long axis, or of a tortoise, being rounded like a shield upon the back, flat upon the belly, and without wings.

These female insects are gathered off the leaves of the nopal plant, after it has ripened

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its fruit, a few only being left for brood, and are killed, either by a momentary immersion in boiling water, by drying upon heated plates, or in ovens: the last become of an ash-gray color, constituting the *silver* cochineal, or *jaspeada;* the second are blackish, called *negra*, and are most esteemed, being probably driest; the first are reddish brown, and reckoned inferior to the other two. The dry cochineal being sifted, the dust, with the imperfect insects and fragments which pass through, are sold under the name of *granillo.*

Cochineal keeps for a long time in a dry place. Hellot says that he has tried some 130 years old, which produced the same effect as new cochineal.

We are indebted to MM. Pelletier and Caventou for a chemical investigation of cochineal, in which its coloring matter was skilfully eliminated.

Purified sulphuric ether acquired by digestion with it a golden yellow color, amounting by Dr. John to one tenth of the weight of the insect. This infusion left, on evaporation, a fatty wax of the same color.

Cochineal, exhausted by ether, was treated with alcohol at 40° B. After 30 infusions in the digester of M. Chevreul, the cochineal continued to retain color, although the alcohol had ceased to have any effect on it. The first alcoholic liquors were of a red verging on yellow. On cooling, they let fall a granular matter. By spontaneous evaporation, this matter, of a fine red color, separated, assuming more of the crystalline appearance. These species of crystals dissolved entirely in water, which they tinged of a yellowish-red.

This matter has a very brilliant purple-red color; it adheres strongly to the sides of the vessels; it has a granular and somewhat crystalline aspect, very different, however, from those compound crystals alluded to above; it is not altered by the air, nor does it sensibly attract moisture. Exposed to the action of heat, it melts at about the fiftieth degree centigrade (122° Fahr.). At a higher temperature it swells up, and is decomposed with the production of carbureted hydrogen, much oil, and a small quantity of water, very slightly acidulous. No trace of ammonia was found in these products.

The coloring principle of cochineal is very soluble in water. By evaporation, the liquid assumes the appearance of sirup, but never yields crystals. It requires of this matter a portion almost imponderable to give a perceptible tinge of bright purplish red to a large body of water. Alcohol dissolves this coloring substance, but, as we have already stated, the more highly it is rectified the less of it does it dissolve. Sulphuric ether does not dissolve the coloring principle of cochineal; but weak acids do, possibly owing to their water of dilution. No acid precipitates it in its pure state. This coloring principle, however, appears to be precipitable by all the acids, when it is accompanied by the animal matter of the cochineal.

The affinity of alumina for the coloring matter is very remarkable. When that earth, newly precipitated, is put into a watery solution of the coloring principle, this is immediately seized by the alumina. The water becomes colorless, and a fine red lake is obtained, if we operate at the temperature of the atmosphere; but if the liquor has been hot, the color passes to crimson, and the shade becomes more and more violet, according to the elevation of the temperature, and the continuance of the ebullition.

The salts of tin exercise upon the coloring matter of cochineal a remarkable action. The muriatic protoxyde of tin forms a very abundant violet precipitate in the liquid. This precipitate verges on crimson, if the salt contains an excess of acid. The muriatic deutoxyde of tin produces no precipitate, but changes the color to scarlet-red. If gelatinous alumina be now added, we obtain a fine red precipitate, which does not pass to crimson by boiling.

To this colouring principle the name *carminium* has been given, because it forms the basis of the pigment called carmine.

The process followed in Germany for making carmine, which consists in pouring a certain quantity of solution of alum into a decoction of cochineal, is the most simple of all, and affords an explanation of the formation of carmine, which is merely the carminium and the animal matter precipitated by the excess of acid in the salt, which has taken down with it a small quantity of alumina; though it appears that alumina ought not to be regarded as essential to the formation of carmine. In fact, by another process called by the name of Madame Cenette of Amsterdam, the carmine is thrown down, by pouring into the decoction of cochineal a certain quantity of the binoxalate of potash. When carbonate of soda is added, then carminated lake also falls down. That carmine is a triple compound of animal matter, carminium, and an acid, appears from the circumstance, that liquors which have afforded their carmine, when a somewhat strong acid is poured into them, yield a new formation of carmine by the precipitation of the last portions of the animal matter. But whenever the whole animal matter is thrown down, the decoctions, although still much charged with the colouring principle, can afford no more carmine. Such decoctions may be usefully employed to make carminated lakes, saturating the acid with a slight excess of alkali, and adding gelatinous alumina. The precipitates obtained, on adding acid to the alkaline decoctions of

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carmines, since they do not contain alumina; but the small quantity of alumina which is thrown down by alum in the manufacture of carmine, augments its bulk and weight It gives, besides, a greater lustre to the color, even though diluting and weakening it a little.

The carmines found in the shops of Paris were analyzed, and yielded the same products. They are decomposed by the action of heat, with the diffusion at first of a very strong smell of burning animal matter, and then of sulphur. A white powder remained, amounting to about one tenth of the matter employed, and which was found to be alumina. Other quantities of carmine were treated with a solution of caustic potash, which completely dissolved them, with the exception of a beautiful red powder, not acted on by potash and concentrated acids, and which was recognised to be red sulphuret of mercury or vermilion. This matter, evidently foreign to the carmine, appears to have been added in order to increase its weight.

The preceding observations and experiments seem calculated to throw some light on the art of dyeing scarlet and crimson. The former is effected by employing a cochineal bath, to which there have been added, in determinate proportions, acidulous tartrate of potash, and nitro-muriatic deutoxyde of tin. The effect of these two salts is now well known. The former, in consequence of its excess of acid, tends to redden the color, and to precipitate it along with the animal matter; the latter acts in the same manner, at first by its excess of acid, then by the oxyde of tin which falls down also with the carmine and animal matter, and is fixed on the wool, with which it has of itself a strong tendency to combine. MM. Pelletier and Caventou remark, that "to abtain a beautiful shade, the muriate of tin ought to be entirely at the maximum of oxydizement; and it is in reality in this state that it must exist in the solution of tin prepared according to the proportions prescribed in M. Berthollet's treatise on dyeing."

We hence see why, in dyeing scarlet, the employment of alum is carefully avoided, as this salt tends to convert the shade to a crimson. The presence of an alkali would seem less to be feared. The alkali would occasion, no doubt, a crimson-colored bath; but it would be easy in this case to restore the color, by using a large quantity of tartar. We should, therefore, procure the advantage of having a bath better charged with coloring matter and animal substance. It is for experience on the large scale to determine this point. As to the earthy salts, they must be carefully avoided; and if the waters be selenitish, it would be a reason for adding a little alkali.

To obtain crimson, it is sufficient, as we know, to add alum to the cochineal bath, or to boil the scarlet cloth in alum water. It is also proper to diminish the dose of the salt of tin, since it is found to counteract the action of the alum.

The alkalis ought to be rejected as a means of changing scarlet to crimson. In fact, crimsons by this process cannot be permanent colors, as they pass into reds by the action of acids.

According to M. Von Grotthuss, carmine may be deprived of its golden shade by ammonia, and subsequent treatment with acetic acid and alcohol. Since this fact was made known, M. Herschel, color maker at Halle, has prepared a most beautiful carmine.

The officers of Her Majesty's Customs have lately detected a system of adulterating cochineal, which has been practised for many years upon a prodigious scale by a mercantile house in London. I have analyzed about 100 samples of such cochineal, from which it appears that the genuine article is moistened with gum-water, agitated in a box or leather bag, first, with sulphate of baryta in fine powder, afterward with bone of ivory black, to give it the appearance of *negra* cochineal, and then dried. By this means about 12 per cent. of worthless heavy spar is sold at the price of cochineal, to the enrichment of the sophisticators, and the disgrace and injury of British trade and manufactures.

The specific gravity of genuine cochineal is 1·25; that of the cochineal loaded with the barytic sulphate, 1·35. This was taken in oil of turpentine and reduced to water as unity, because the waxy fat of the insects prevents the intimate contact of the latter liquid with them, and the ready expulsion of air from their wrinkled surface. They are not at all acted upon by the oil, but are rapidly altered by water, especially when they have been gummed and barytified.

	Landed.	Delivered.	Stock, 1st of January.
December, 1851 - -	1,203 bags	692 bags	— bags
1850 - -	1,605 —	595 —	— —
12 Months, 1851 - -	16,561 —	16,180 —	9,001 —
1850 - -	17,765 —	13,096 —	8.620 —
1849 - -	12.604 —	13,594 —	3,951 —
1848 - -	13,521 —	11.506 —	4.933 —

Humboldt states that so long ago as the year 1736, there was imported into Europe from South America cochineal to the value of 15 millions of francs. Its high price had for a long time induced dyers to look out for cheaper substitutes in dyeing red, and since science has introduced so many improvements in tinctorial processes, both madder and lac have been made to supersede cochineal to a very great extent. Its price has, in

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consequence of this substitution, as well as from more successful modes of cultivation, fallen very greatly of late years. In January, 1852, the prices of Honduras cochineal ranged from 2*s.* 9*d.* to 5*s.* per lb., and Mexican from 2*s.* 7*d.* to 3*s.* 4*d.* per lb.

COCOA, STEARINE, and ELAINE. Mr. Soames obtained a patent in September, 1829, for making these useful articles, by the following process:—

He takes the substance called cocoa-nut oil, in the state of lard, in which it is imported into this country, and submits it to a strong hydraulic pressure, having made it up in small packages, 3 or 4 inches wide, 2 feet long, and 1 or 1½ inches thick. These packages are formed by first wrapping up the said substance in a strong linen cloth, of close texture, and then in an outward wrapper of strong sail cloth. The packages are to be placed side by side, in single rows, between the plates of the press, allowing a small space between the packages for the escape of the *elaine.*

The temperature at which the pressure is begun, should be from about 50 to 55 degrees, or in summer as nearly at this pitch as can be obtained, and the packages of the said substance intended for pressure, should be exposed for several hours previously to about the same temperature. When the packages will no longer yield their oil or elaine freely at this temperature, it is to be gradually raised; but it must at no time exceed 65 degrees, and the lower the temperature at which the separation can be effected, the better will be the quality of the oil expressed.

When the packages are sufficiently pressed, that is, when they will give out no more oil, or yield it only in drops at long intervals, the residuum in them is to be taken out and cleansed and purified, which is done by melting it in a well-tinned copper vessel, which is fixed in an outer vessel, having a vacant space between, closed at the top, into which steam is admitted, and the heat is kept up moderately for a sufficient time to allow the impurities to subside; but if a still higher degree of purity is required, it is necessary to pass it through filters of thick flannel lined with blotting paper.

Having been thus cleansed or purified, it is fit for the manufacture of candles, which are made by the ordinary process used in making mould tallow candles. Having thus disposed of the stearine, or what is called the first product, he proceeds with the elaine or oil expressed from it, and which he calls the second product, as follows: that is to say, he purifies it by an admixture, according to the degree of its apparent foulness, of from 1 to 2 per cent. by weight of the sulphuric acid of commerce, of about 1·80 specific gravity, diluted with six times its weight of water. The whole is then to be violently agitated by mechanical means, and he prefers for this purpose the use of a vessel constructed on the principle of a common barrel churn. When sufficiently agitated, it will have a dirty whitish appearance, and is then to be drawn off into another vessel, in which it is to be allowed to settle, and any scum that rises is to be carefully taken off. In a day or two the impurities will be deposited at the bottom of the oil, which will then become clear, or nearly so, and it is to be filtered through a thick woollen cloth, after which it will be fit for burning in ordinary lamps and for other uses.

The process of separating the elaine from the stearine, by pressure, in manner aforesaid, had never before been applied to the substance called cocoa-nut oil, and consequently no product had heretofore been obtained thereby from that substance, fit for being manufactured into candles in the ordinary way, or for being refined by any of the usual modes, so as to burn in ordinary lamps, both which objects are obtained by this method of preparing or manufacturing the said substance.

Candles well made from the above material are a very superior article. The light produced is more brilliant than from the same sized candle made of tallow; the flame is perfectly colorless, and the wick remains free from cinder, or any degree of foulness during combustion.

COFFEE. The coffee is the seed of a tree of the family *rubiaceæ,* and belongs to the Pentandria monogynia of Linnæus. There are several species of the genus, but the only one cultivated is the *Coffæa Arabica,* a native of Upper Ethiopia and Arabia Felix. It rises to the height of 15 or 20 feet; its trunk sends forth opposite branches in pairs above and at right angles to each other; the leaves resemble those of the common laurel, although not so dry and thick. From the angle of the leaf-stalks small groups of white flowers issue, which are like those of the Spanish jasmine. These flowers fade very soon, and are replaced by a kind of fruit not unlike a cherry, which contains a yellow glairy fluid, enveloping two small seeds or berries convex upon one side, flat and furrowed upon the other in the direction of the long axis. These seeds are of a horny or cartilaginous nature; they are glued together, each being surrounded with a peculiar coriaceous membrane. They constitute the coffee of commerce.

It was not till towards the end of the 15th century that the coffee-tree began to be cultivated in Arabia. Historians usually ascribe the discovery of the use of coffee as a beverage to the superior of a monastry there, who, desirous of preventing the monks from sleeping at their nocturnal services, made them drink the infusion of coffee upon the report of shepherds, who pretended that their flocks were more lively after browsing on the fruit of that plant. The use of coffee was soon rapidly spread, but it encountered much

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opposition on the part of the Turkish government, and became the occasion of public assemblies. Under the reign of Amurath III. the mufti procured a law to shut all the coffee-houses, and this act of suppression was renewed under the minority of Mahomet IV. It was not till 1554, under Solyman the Great, that the drinking of coffee was accredited in Constantinople; and a century elapsed before it was known in London and Paris. Solyman Aga introduced its use into the latter city in 1669, and in 1672 an Armenian established the first *café* at the fair of Saint Germain.

When coffee became somewhat of a necessary of life, from the influence of habit among the people, all the European powers who had colonies between the tropics, projected to form plantations of coffee-trees in them. The Dutch were the first who transported the coffee plant from Moka to Batavia, and from Batavia to Amsterdam. In 1714 the magistrates of that city sent a root to Louis XIV., which he caused to be planted in the Jardin du Roi. This became the parent stock of all the French coffee plantations in Martinique.

The most extensive culture of coffee is still in Arabia Felix, and principally in the kingdom of Yemen, towards the cantons of Aden and Moka. Although these countries are very hot in the plains, they possess mountains where the air is mild. The coffee is generally grown half way up on their slopes. When cultivated on the lower grounds it is always surrounded by large trees which shelter it from the torrid sun, and prevent its fruit from withering before their maturity. The harvest is gathered at three periods; the most considerable occurs in May, when the reapers begin by spreading cloths under the trees, then shaking the branches strongly, so as to make the fruit drop, which they collect, and expose upon mats to dry. They then pass over the dried berries a very heavy roller, to break the envelops, which are afterwards winnowed away with a fan. The interior bean is again dried before being laid up in store.

In Demarara, Berbice, and some of our West India islands, where much good coffee is now raised, a different mode of treating the pulpy fruit and curing the beans is adopted. When the cherry-looking berry has assumed a deep-red color it is gathered, and immediately subjected to the operations of a mill composed of two wooden rollers, furnished with iron plates, which revolve near a third fixed roller called the *chops*. The berries are fed into a hopper above the rollers, and falling down between them and the chops, they are stripped of their outer skin and pulp, while the twin beans are separated from each other. These beans then fall upon a sieve, which allows the skin and the pulp to pass through, while the hard beans accumulate and are progressively slid over the edge into baskets. They are next steeped for a night in water, thoroughly washed in the morning, and afterwards dried in the sun. They are now ready for the peeling mill, a wooden edge wheel turned vertically by a horse yoked to the extremity of its horizontal axis. In travelling over the coffee, it bursts and detaches the coriaceous or parchment-like skin which surrounds each hemispherical bean. It is then freed from the membranes by a winnowing machine, in which four pieces of tin made fast to an axle are caused to revolve with great velocity. Corn fanners would answer better than this rude instrument of negro invention. The coffee is finally spread upon mats or tables, picked clean, and packed up for shipment.

The most highly esteemed coffee is that of Moka. It has a smaller and a rounder bean; a more agreeable taste and smell than any other. Its color is yellow. Next to it in European reputation are the Martinique and Bourbon coffees; the former is larger than the Arabian, and more oblong; it is rounded at the ends; its color is greenish, and it preserves almost always a silver gray pellicle, which comes off in the roasting. The Bourbon coffee approaches nearest to the Moka, from which it originally sprung. The Saint Domingo coffee has its two extremities pointed, and is much less esteemed than the preceding.

The coffee-tree flourishes in hilly districts, where its root can be kept dry, while its leaves are refreshed with frequent showers. Rocky ground, with rich decomposed mould in the fissures, agrees best with it. Though it would grow, as we have said, to the height of 15 or 20 feet, yet it is usually kept down by pruning to that of five feet, for increasing the production of the fruit, as well as for the convenience of cropping. It begins to yield fruit the third year, but is not in full bearing till the fifth, does not thrive beyond the twenty-fifth, and is useless in general at the thirtieth. In the coffee husbandry, the plants should be placed eight feet apart, as the trees throw out extensive horizontal branches, and in holes ten or twelve feet deep, to secure a constant supply of moisture.

Coffee has been analyzed by a great many chemists, with considerable diversity of results. The best analysis perhaps is that of Schrader. He found that the raw beans distilled with water in a retort communicated to it their flavor and rendered it turbid, whence they seem to contain some volatile oil. On reboiling the beans, filtering, and evaporating the liquor to a sirup, adding a little alcohol till no more matter was precipitated, and then evaporating to dryness, he obtained 17·58 per cent. of a yellowish brown transparent extract, which constitutes the characteristic part of coffee, though it is not in that state the pure proximate principle, called *caffeine*. Its most remarkable reaction is its producing, with both the protoxyde and the peroxyde salts of iron, a fine grass green color, while a dark green precipitate falls, which re-dissolves when an acid is poured into the liquor. It produces on the solution of the salts of copper scarcely any effect, till an alkali be added, when a very beautiful green color is produced, which may be employed in painting. Coffee beans contain also a resin, and a fatty substance somewhat like suet. According to Robiquet, ether extracts from coffee beans nearly 10 per cent. of resin and fat, but he probably exaggerates the amount. The peculiar substance cafeine contained in the above extract is crystallizable. It is remarkable in regard to composition, that after urea and the uric acid, it is among organic products the richest in azote. It was discovered and described in 1820 by Runge. It does not possess alkaline properties. Pfaff obtained only 90 grains of cafeine from six pounds of coffee beans. There is also an acid in raw coffee, to which the name of *cafeic acid* has been given. When distilled to dryness and decomposed, it has the smell of roasted coffee.

Coffee undergoes important changes in the process of roasting. When it is roasted to a yellowish brown it loses, according to Cadet, 12½ per cent. of its weight, and is in this state difficult to grind. When roasted to a chestnut brown it loses 18 per cent., and when it becomes entirely black, though not at all carbonized, it has lost 23 per cent. Schrader has analyzed roasted coffee comparatively with raw coffee, and he found in the first 12½ per cent. of an extract of coffee, soluble in water and alcohol, which possesses nearly the properties of the extract of the raw coffee, although it has a deeper brown color, and softens more readily in the air. He found also 10·4 of a blackish brown gum; 5·7 of an oxygenated extract, or rather *apo'hème*, soluble in alcohol, insoluble in water; 2 of a fatty substance and resin; 69 of burnt vegetable fibre, insoluble. On distilling roasted coffee with water, Schrader obtained a product which contained the aromatic principle of coffee; it reddened litmus paper, and exhaled a strong and agreeable odor of roasted coffee. If we roast coffee in a retort, the first portions of the aromatic principle of coffee condense into a yellow liquid in the receiver; and these may be added to the coffee roasted in the common way, from which this matter has been expelled and dissipated in the air.

Chenevix affirmed that by the roasting of coffee a certain quantity of tannin possessing the property of precipitating gelatin is generated. Cadet made the same observation, and found, moreover, that the tannin was most abundant in the lightly roasted coffee, and that there was nearly none of it in coffee highly roasted. Payssé and Schrader, on the contrary, state that solution of gelatin does not precipitate either the decoction of roasted coffee or the alcoholic extract of this coffee. Runge likewise asserts that he could obtain no precipitate with gelatin; but he says that albumen precipitates from the decoction of roasted coffee the same kind of tannin as is precipitated from raw coffee by the acetate of lead, and set free from the lead by sulphureted hydrogen. With these results my own experiments agree. Gelatin certainly does not disturb clear infusion of roasted coffee, but the salts of iron blacken it.

Schrader endeavored to roast separately the different principles of coffee, but none of them exhaled the aromatic odor of roasted coffee except the horny fibrous matter. He therefore concludes that this substance contributes mainly to the characteristic taste of roasted coffee, which cannot be imitated by any other vegetable matter, and which, as we have seen, should be ascribed chiefly to the altered cafeic acid. According to Garot, we may extract the cafeine without alteration from roasted coffee by precipitating its decoction by subacetate of lead, treating the washed precipitate with sulphureted hydrogen, and evaporating the liquid product to dryness.

Of late years, much ingenuity has been expended in contriving various forms of apparatus for making infusions of coffee for the table. I have tried most of them, and find, after all, none so good as a *cafetière à la Belloy*, the coffee *biggin*, with the perforated tin-plate strainer, especially when the filtered liquor is kept simmering in a close vessel, set over a lamp or steam pan. The useful and agreeable matter in coffee is very soluble: it comes off with the first waters of infusion, and needs no boiling.

To roast coffee rightly we should keep in view the proper objects of this process, which are to develop its aroma, and destroy its toughness, so that it may be readily ground to powder. Too much heat destroys those principles which we should wish to preserve, and substitutes new ones which have nothing in common with the first, but add a disagreeable empyreumatic taste and smell. If, on the other hand, the rawness or greenness is not removed by an adequate heat, it masks the flavor of the bean, and injures the beverage made with it. When well roasted in the sheet-iron cylinders set to revolve over a fire, it should have a uniform chocolate color, a point readily hit by experienced roasters, who now manage the business very well for the principal coffee-dealers both of London and Paris, so far as my judgment can determine. The development of the proper aroma

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is a criterion by which coffee roasters frequently regulate their operations. When it loses more than 20 per cent. of its weight, coffee is sure to be injured. It should never be ground till immediately before infusion.

Liebig's views of the process of nutrition have given fresh interest to every analysis of articles of food. A watery infusion of coffee is used in almost every country as a beverage, and yet it is uncertain whether it is an article of nutrition or merely a condiment. A minute examination of the raw seed, or coffee bean as it is called, must precede the determination of that disputed point. Caffeine is the principle best known, being most easily separated from the other substances, resisting most powerfully chemical reagents, and by assuming a crystalline state is discoverable in very small quantities.

The constituents of coffee are: 1. *Vegetable fibrine*, which is the largest constituent, being an elastic horny substance, in which the other substances are incorporated. If we dry the beans at the heat of boiling water for several weeks we can easily reduce them to a fine powder, and by washing with ether, and then boiling in alcohol and water, we extract the soluble matter from the fibrine, which may then be boiled with weak solution of potash, and afterwards weak muriatic acid, as long as any matter is taken up. The purification being completed by boiling in water the fibrine remains; and when rubbed in a mortar resembles starch; when roasted it gives out the odor nearly of wood.

2. *Fatty matter:* the beans digested in ether give out a yellow-colored matter, which on evaporation becomes buttery with an odor of raw coffee, and amounts to $10\frac{0}{0}$ of the beans.

3. *Caffeine:* the ethereal solution contains caffeine, which may be removed by shaking with a solution of water.

4. *Legumine:* in addition to an *acid* which agrees in its properties with the acid found in oak and cinchona, we find in the coffee beans legumine similar to that of beans. The legumine contains sulphur, which is the cause of their blackening a silver vessel in which the beans may be boiled with an alkali. Legumine and caffeine are the only nitrogenous constituents of coffee beans, consequently the only substances which could be nutritious, but they are not soluble in hot water as they exist in roasted coffee, and therefore it may be reckoned merely an exhilarating beverage.

Roasted coffee affords a much richer infusion to hot water containing a minute quantity of carbonate of soda, and improves the quality of coffee on the stomach, by neutralizing the caffeic acids.

Coffee is sold in the shops in its roasted and ground state often adulterated with a variety of substances, but chiefly with chicory. This is the dried, roasted, and ground root of a plant called *Cichorium Intybus*, better known under the name of wild succory. The chicory imported from Belgium and Prussia is better than the British, which is usually colored with Venetian red, and is sold at a cheaper rate; chicory itself is frequently very impure, containing roasted peas and coffee flights, which are the membranous coat of the bean separated in the act of roasting. If a little genuine ground coffee be thrown in a wineglassfull of water, it mostly floats, and slowly moistens, communicating scarcely any color to the liquid. Powdered chicory treated in the same way very speedily absorbs moisture, communicates a deep reddish brown tint to the water, and in a few minutes falls to the bottom. Hambro' powder contains roasted starch, and acquires a deep purplish color when moistened with a solution of iodine. The microscope shows in the chicory powder fragments of dotted ducts which do not exist in coffee. There is another substance which is mixed with coffee, called refining powder; it is merely caramel, or burnt sugar. It is used for enabling drained coffee to afford a dark colored infusion.

If tannin exists in roasted coffee, as maintained long ago by Chenevix, and generally admitted since, it must be very different from the tannin present in tea, catechu, kino, oak-bark, willow-bark, and other astringent vegetables; for I find that it is not, like them, precipitated by either gelatine, albumen, or sulphate of quinine. With regard to the action upon the animal economy of coffee, tea, and cocoa, which contain one common chemical principle called caffeine or theine, Liebig has lately advanced some ingenious views, and has, in particular, endeavored to show that, to persons of sedentary habits in the present refined state of society, they afford eminently useful beverages, which contribute to the formation of the characteristic principle of *bile*. This important secreted fluid, deemed by Liebig to be subservient to the function of respiration, requires for its formation much azotised matter, and *that* in a state of combination analogous to what exists in caffeine. The quantity of this principle in tea and coffee being only from 2 to 5 per cent. might lead one to suppose that it could have little effect upon the system even of regular drinkers of their infusions; but if the bile contains only one-tenth of solid matter, called choleic acid, which contains less than 4 per cent. of azote, then it may be shown that 3 grains of caffeine would impart to 500 grains of bile the azote which occurs in that crystalline precipitate of bile called *taurine*, which is thrown down from it by by mineral acids.

One atom of caffeine, 9 atoms of oxygen, and 9 of water, being placed together, produce the composition of 2 atoms of taurine. Now this is a very simple combination for the living organism to effect; one already paralleled in the generation of hippuric acid in urine, by the introduction of benzoic acid into the stomach; a physiological discovery made by my son, which is likely to lead to a more successful treatment of some of the most formidable diseases of man, particularly gout and gravel.

If the preceding views be established, they will justify the instinctive love of mankind for tea, coffee, and cocoa, in spite of the denunciations and veto of *neuropathic*, *homeœpathic*, and *hydropathic* doctors; sorry pathologists—*hoc genus omne*. See Tea.

In the years ending 5th January, 1851 and 1852, the imports of coffee were as follows:—

	Importations.		Entries for Home Consumption.		Gross Amount of Duty.	
	1851.	1852.	1851.	1852.	1851.	1852.
Entered before 15th April 1851·	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Of British Possessions	36,814,036	1,818,514	28,891,294	6,510,346	505,515	113,931
Foreign	13,989,116	5,018,806	2,335,546	443,418	61,305	11,637
Entered from 15th April, 1851: from British Possessions out of Europe	- -	34.077.563	- -	21,486,170	- -	268,599
From other Parts	- -	12,035,269	- -	4,124,230	- -	51,572
	50,803,152	52,950,152	31,226,840	32.564,164	566,820	445,739

The duty is 3*d.* per lb. The exports in the above years were respectfully 12,169,752 lbs. and 22,712,859 lbs. of which 3,399,333 lbs. and 12,606,333 lbs. were the produce of British Possessions, and 8,770,419 lbs. and 10,106,526 lbs. were Foreign.

Coffee Roasting and Grinding. The gratefulness of the beverage afforded by this seed depends upon many circumstances, which are seldom all combined. The nature of the soil, the climate, seed, mode of culture, and cure, influence greatly the quality of the fruit. But when all these particulars concur, and the berry is of the finest sort, and most highly appreciated by the importer, it may be ruined in the roasting; for if some berries be under and some over done, the whole when ground will yield an unpalatable infusion. The due point to which the torrefaction should be carried, may be determined partly by the color, and partly by the loss of weight, which points, however, are different for each sort of coffee. But perfect equality of ustulation is difficult of attainment with the ordinary cylindrical machines. Messrs. Law, of London and Edinburgh, coffee merchants to the Queen, had long been dissatisfied with the partial manner in which the cylinder performed its duty, as it generally left some part of its contents black, some dark brown, and others paler; results which greatly injure the flavor of the beverage made with the coffee. Mr. William Law has conquered all these difficulties by his happy invention of the globular roaster, actuated by a compound motion like that of our earth. This roaster, with its double, rotary motion, is heated not over an open fire but in an atmosphere of hot air, through a cast metal casing. The globe is so mounted as to revolve horizontally, and also from time to time vertically, whereby the included beans were tossed about and intermingled in all directions. Inequality of torrefaction becomes impossible. The consequence is the production of an article which on being ground evolves the most fragrant aroma, and when infused the most grateful and exhilarating beverage. The position of the globe in *fig.* 366 shows

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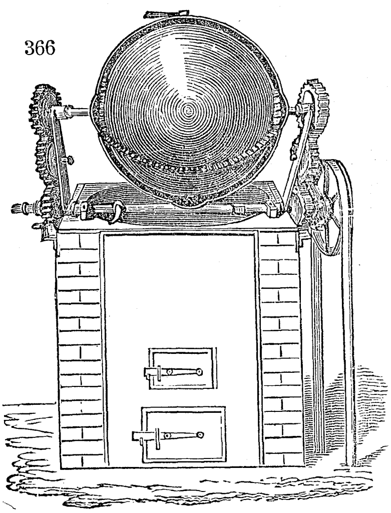

it as turned up by a powerful leverage out of the cast-iron heater, preparatory to its being emptied and re-charged.

The coffee, thus equally roasted, is finely ground in a mill between horizontal stones, like that of a corn-mill, and is thereby capable of giving out all its virtues to either boiling or cold water.

COKE is carbonized pitcoal. See CHARCOAL; and PITCOAL at the end.

In manufacturing coke on the large scale, Mr. Wilkinson of Jarrow, near Gateshead, has contrived a system of machinery for saving manual labor in discharging the coke from the ovens, while he has so arranged the ovens themselves, as to equalize the distribution of air among the coals, and to improve the produce and increase its quantity. The preferable size of oven, in his opinion, is 14 feet long, 8 feet wide, with the floor raised one foot above the level of the ground, and having an inclination to the front of 6 inches in the length of the bottom; the perpendicular height of the walls, up to the springer, being 3 feet, while the radius of the arch is 4 feet. He connects crystallizing and evaporating pans for chemical purposes with a range of 12 coke ovens. The patentee claims as inventions his forming in the walls of coke ovens, flues with lateral openings for supplying air to the interior of the oven, as also his peculiar mechanical apparatus for discharging the coke, and his plan of economizing heat by evaporation.

COLCOTHAR OF VITRIOL (*Rouge d'Angleterre*, Fr.; *Rothes Eisenoxgd*, Germ.) is the brown-red peroxide of iron, produced by calcining sulphate of iron with a strong heat, levigating the resulting mass, and elutriating it into an impalpable powder. A better way of making it so as to complete the separation of the acid, is to mix 100 parts of the green sulphate of iron with 42 of common salt, to calcine the mixture, wash away the resulting sulphate of soda, and levigate the residuum. The sulphuric acid in this case expels the chlorine of the salt in the form of muriatic acid gas, and saturates its alkaline base produced by the chemical reaction; whence an oxide will be obtained free from acid, much superior to what is commonly found in the shops. The best sort of polishing powder, called *jeweller's red rouge*, or plate powder, is the precipitated oxide of iron prepared by adding solution of soda to solution of copperas, washing, drying, and calcining the powder in shallow vessels with a gentle heat, till it assumes a deep brown-red color. See IRON.

COLLODION. M. Malgaigne has recently communicated to the French Medical Journals, some remarks on the preparation of gun-cotton for surgical purposes. Several French chemists, at the suggestion of M. Malgaigne, attempted to make an ethereal solution of this compound, by pursuing the process recommended by Mr. Maynard in the American Journal of Medical Sciences, but they failed in procuring the cotton in a state in which it could be dissolved in ether. It appears that these experimentalists had employed a mixture of nitric and sulphuric acids; but M. Miallie ascertained, after many trials, that the collodion, in a state fitted for solution, was much more easily procured by using a mixture of nitrate of potash and sulphuric acid.

For the information of our readers who may be disposed to try this new adhesive material, we here give a description of M. Miallie's process for its preparation. It appears from the results obtained from this chemist, that cotton, in its most explosive form, is not the best fitted for making the ethereal solution—

	Parts by weight.
Finely powdered nitrate of potash - - - - - -	40
Concentrated sulphuric acid - - - - - - -	60
Carded cotton - - - - - - - - -	2

Mix the nitrate with the sulphuric acid in a porcelain vessel, then add the cotton, and agitate the mass for three minutes by the aid of two glass rods. Wash the cotton, without first pressing it, in a large quantity of water, and when all acidity is removed (indicated by litmus paper) press it firmly in a cloth. Pull it out into a loose mass, and dry it in a stove at a moderate heat.

The compound thus obtained is not pure fulminating cotton; it always retains a small quantity of sulphuric acid, is less inflammable than gun-cotton, and it leaves a carbonaceous residue after explosion. It has, however, in a remarkable degree, the property of solubility in ether, especially when mixed with a little alcohol, and it forms therewith a very adhesive solution, to which the name of collodion has been applied.

Preparation of Collodion.

	Parts by weight.
Prepared cotton - - - - - - - -	8
Rectified sulphuric ether - - - - - - -	125
Rectified alcohol - - - - - - - - -	8

Put the cotton with the ether into a well-stopped bottle, and shake the mixture for some minutes. Then add the alcohol by degrees, and continue to shake until the whole

COLORS USED IN PAINTING, WITH NOTICES OF THEIR CHEMICAL AND ARTISTICAL PROPERTIES.—*By William Linton.*

			Colors.	Chemical Designation.	Preparation.	Chemical Characteristics.	Artistical Properties.	Additional Colors, with Remarks.
MINERAL.	SAFELY USED AS PERMANENT ONES.	WHITES.	FLAKE WHITE	Carbonate of Lead, with an excess of Oxide.	Plates of lead exposed to the action of vinegar-steam in beds of fermenting tan.	Blackened by Sulphuretted Hydrogen, Hydro-Sulphuret of Ammonia, and other foul gases, common to most domestic atmospheres; for which reason a rapidly drying and protective vehicle is essential to seal it up against such evil influences. It has no injurious action upon Vegetable and other colors, as some have conjectured. It is perfectly soluble in diluted Nitric or Acetic Acid when free from Pipe-clay or Sulphate of Barytes.	The best White extant for Oil or Resin vehicles when pure, which is generally ascertained by its exceeding whiteness and opacity. Its usual adulterations are Sulphate of Barytes, Chalk, Pipe-clay, &c., all of which are partially transparent, and consequently appear darker in unctnous or resinous vehicles.	There are other Whites of Lead, varying in body and brilliancy, and equally obnoxious to the action of mephitic vapors; as *Krems*, *Roman*, and *Venetian Whites*, and *Sulphate of Lead*. The Whites of *Bismuth*, *Pearl*, and *Antimony*, are injured by light as well as by mephitic vapors. Those of *Zinc*, *Tin*, *Barytes*, and *Strontian*, although they are comparatively secure against the foul gases, are too feeble in body to be satisfactory in unctuous or resinous vehicles.
		YELLOWS.	CADMIUM YELLOW	Sulphuret of Cadmium	A combination of Cadmium and Sulphur.	Resists the action of the foul gases, light, &c. It is a most durable and brilliant color.	A beautiful Orange tinted Yellow, of an excellent body; and an admirable substitute for Naples Yellow, the Chromes, and other Mineral Yellows, which are liable to injury from noxious vapors, light, &c.	There are other Mineral Yellows, but they are all more or less objectionable. The *Chromates of Lead*, like all preparations of that metal, are blackened by the foul gases. The *Chromate of Barytes* is strongly acted upon by light. The united oxides of Lead and Antimony, furnish *Naples Yellow*, a color readily affected by Sulphuretted Hydrogen and other foul gases, as well as by light, and by a moist steel spatula. *Turpith Mineral*, or Subsulphate of Mercury, is rapidly blackened by light, and by the foul airs. *Orpiment* or *King's Yellow* (Arsenic and Sulphur) is equally destructible; also *Patent Yellow* (Lead and Salt heated violently). The Vegetable Yellows are not to be depended upon. They soon disappear when applied in delicate tints or thin glazings, especially if subjected to the action of the solar rays (a summary mode of ascertaining the probable results of lengthened periods in subdued lights). *Gamboge* dissolved by Æther, or Alcohol, is equally fugitive.
			STRONTIAN YELLOW	Chromate of Strontian	A Solution of Strontian added to one of Chromate of Potash.	Resists the action of the foul gases and light, and is perfectly durable.	A pale Canary Yellow; another safe substitute for the faulty Yellows mentioned above.	
			YELLOW OCHRE OXFORD OCHRE ROMAN OCHRE STONE OCHRE BROWN OCHRE TERRA DI SIENNA UMBER	Oxides of Iron.	Native Earths, consisting of Silica and Alumina colored by Oxide of Iron.	All Permanent Colors, whether Native or Calcined.	The Oxides of Iron are among the most staple colors of the palette. When properly washed and prepared for oil painting, they are incapable of injuring other colors, and may be said to constitute the soundest materials with which the chemistry of Nature has furnished the painter for the imitation of her works.	
			JAUNE DE MARS		A Chemical Preparation			
		REDS.	LIGHT RED		Yellow Ochre, Calcined.			There are other Mineral Reds which are durable; but they are of inferior quality and are not needed. *Native Cinnabar* is inferior in every respect to Vermillion. *Venetian Red* is an inferior representative of Indian Red, and *Colcothar* a still coarser one. *Red Lead* blackens in oil; and *Iodide of Mercury* has no claim to durability. Among Vegetable Reds, the *Madders* have the best reputation for standing. All vegetable colors, however, should be looked upon with suspicion.
			INDIAN RED		A Native Earth.			
			VERMILLION	Bisulphuret of Mercury.	Mercury and Sulphur. sublimed together.	A perfectly permanent color, not affected by acids or caustic alkalies. Vaporized by a red heat if pure.	A beautiful color, and of an excellent body	

MINERAL.	ALL THESE COLORS MAY BE	BLUES.	NATIVE ULTRAMARINE	Consists of Silica, Alumina, Lime, Soda, and Potash, Oxide of Iron, Magnesia, Sulphuric Acid, Sulphur, and Chlorine (according to Gmelin, Varrentrapp, and others), in its native state.	Prepared from a mineral called Lapis Lazuli.	Acids, which will not affect other Mineral Blues, will destroy the color in Ultramarine. This is one of its best chemical tests. None of the mephitic gases, or light, or other pigments do it any injury. It is perfectly durable.	A most invaluable pigment: too well known and appreciated to require any comment.	There are other Mineral Blues, but they are better avoided when the Ultramarines are available. The Oxide of Cobalt and Alumina form *Cobalt Blue;* and the Oxide of Cobalt and Glass, form *Smalt;* they are both blackened by foul airs. *Prussian* and *Antwerp Blues* are in much use from the want of a permanent deep blue: they are injured by light and alkalies. ***Indigo*** **is inferior** in color and very fugitive.
			ARTIFICIAL ULTRAMARINE	It is regarded as a compound of Silicate of Alumina, Silicate of Soda, with Sulphuret of Sodium; the color is owing to the reaction of the latter on the two former constituents.	Prepared by several difficult processes, some of which are kept secret by the makers.	Responds to the same tests as the native mineral.	A cheap and really valuable substitute for the native product. The best is that which is the least purple in its tint.	
		GREENS.	CHROME GREEN	Sesquioxide of Chromium.	When Chromate of Mercury (the Orange precipitate on mixing Nitrate of Mercury and Chromate of Potash) is strongly ignited, Oxide of Chromium remains in a powder.	A permanent color in all respects. (The coloring matter of emeralds.).	An opaque light Green, of a full body.	There are other Mineral Greens. Those of Copper, the *Emerald Green* and *Mineral Green*, are very insecure in oil vehicles.
			TERRA VERTE	Oxide of Copper.	Native Minerals.	Both quite permanent—native or calcined. Like the Ultramarines, acids destroy their colors.	Beautiful delicate Greens; deservedly favorite pigments with most painters.	
			MALACHITE	Carbonate of Copper, united with Silicate.				
Veg.		BROWNS.	VANDYKE BROWN COLOGN EARTH	Decomposed Vegetable Matter.	Decayed Wood, Peat, or Bog Earth.	These Browns are reputed permanent in themselves, the opacity with which time generally invests them in pictures, being attributable probably to a loss of translucency in the vehicle, rather than to any change in the pigments: dark colors making the defect more evident than light ones.	Dark transparent Brown.	The dark Browns, though chiefly of vegetable *origin*, seem to be the only deep transparent colors which have the reputation of being permanent. The deep Reds, Yellows, Greens, and Blues, are all more or less of a fugitive nature.
Anl.			MUMMY	Vegetable and Animal Matter combined.	White Pitch and Myrrh, with Animal Matter.			
Bitn.			ASPHALTUM	Bitumen.	A Mineral Pitch, or Resin, found floating on the Dead Sea; also after the distillation of natural naphtha.			
Carb.		BLACKS.	IVORY BLACK	Animal Matter.	Calcined Ivory.	A perfectly durable pigment.	Of a Brownish-black tint.	
			BLUE BLACK	Vegetable Matter.	Calcined Vine Stalks. Cocoa-Nut Shells, &c.	Quite durable when the blue tints natural.	Of a Bluish-black tint.	

In recording the defects and liabilities of colors, it should not be forgotten that the painter's vehicle or diluent must have considerable effect in preventing chemical action among such as are inimical to each other, by isolating and sustaining their component particles from mutual contact. And if the vehicle be of a sound and firmly drying quality, even the external attacks from damp and foul airs, to which many of the objectionable colors are liable, may often be successfully resisted. But should the vehicle be of a flimsy and impure character, instead of being a protector, it may become in itself an originator of mischief among the colors.

of the liquid acquires a syrupy consistency. It may be then passed through a cloth, the residue strongly pressed, and the liquid kept in a well-secured bottle.

Collodion thus prepared possesses remarkably adhesive properties. A piece of linen or cotton cloth covered with it and made to adhere by evaporation to the palm of the hand, will support a weight of twenty or thirty pounds. Its adhesive power is so great that the cloth will commonly be torn before it gives way. The collodion cannot be regarded as a perfect solution of the cotton. It contains suspended and floating in it a quantity of vegetable fibre, which has escaped the solvent action of the ether. The liquid portion may be separated from these fibres by a filter, but it is doubtful whether this is an advantage. In the evaporation of the liquid, these undissolved fibres by felting with each other appear to give a greater degree of tenacity and resistance to the dried mass.

In the preparation of collodion it is indispensable to avoid the presence of water, as this renders it less adhesive; hence the ether as well as the alcohol should be purely rectified. The parts to which the collodion is applied should be first thoroughly dried, and no water allowed to come in contact with them until all the ether is evaporated to dryness by a steam heat, which must be continued for some time so as entirely to expel the alcohol or ether. The residuary matter should have the transparency and general characters of common resin.

COLOPHANY, black rosin, the solid residuum of the distillation of turpentine, when all the oil has been worked off.

COLORING MATTER. (*Matière colorante*, Fr.; *Farbstoff*, Germ.) See DYEING, the several dye-stuffs and pigments.

COLUMBIUM, a peculiar metal extracted from a rare mineral brought from Haddam, in Connecticut. It is also called Tantalium, from the mineral *tantalite* and *yttro-tantalite*, found in Sweden. It has hitherto no application to the arts. It combines with two successive doses of oxygen; by the second it becomes an acid.

COLZA is a variety of cabbage, the *brassica oleracea*, whose seeds afford, by pressure, an oil much employed in France and Belgium for burning in lamps, and for many other purposes. This plant requires a rich but light soil; it does not succeed upon either sandy or clayey lands. The ground for it must be deeply ploughed and well dunged. It should be sown in July, and be afterward replanted in a richly-manured field. In October it is to be planted out in beds, 15 or 18 inches apart. Colza may also be sowed in furrows 8 or 10 inches asunder.

Land which has been just cropped for wheat is that usually destined to colza; it may be fresh dunged with advantage. The harvest takes place in July, with the sickle, a little before the seeds are completely ripe, lest they should drop off. As the seed is productive of oil, however, only in proportion to its ripeness, the cut plants are allowed to complete their maturation, by laying them in heaps under airy sheds, or placing them in a stack, and thatching it with straw.

The cabbage-stalks are thrashed with flails, the seeds are winnowed, sifted, spread out in the air to dry; then packed away in sacks, in order to be subjected to the oil-mill at the beginning of winter. The oil-cake is a very agreeable food to cattle, and serves to fatten them. It is reckoned to defray the cost of the mill.

Colza impoverishes the soil very much, as do, indeed, all the plants cultivated for the sake of their oleaginous seeds. It must not, therefore, be come back upon again for six years, if fine crops be desired. The double ploughing which it requires effectually cleans the ground. See OILS, UNCTUOUS.

COMB, the name of an instrument made of a thin plate either plane or curved of wood, horn, tortoise-shell, ivory, bone, or metal, cut out upon one or both of its sides or edges, into a series of somewhat long teeth, not far apart; which is employed for disentangling, laying parallel and smooth the hairs of man, horses, or other animals.

A thin steel saw bow, mounted in an iron or wooden handle, is the implement used by the comb-maker to cut the bone, ivory, and wood into slices of from a twelfth to a quarter of an inch thick, and of a size suitable to that of the comb. The pieces of tortoise-shell as found in commerce are never flat, or, indeed, of any regular curvature, such as the comb must have. They are therefore steeped in boiling water sufficiently long to soften them, and set to cool in a press between iron or brass moulds, which impart to them the desired form which they preserve after cooling. After receiving their outline shape and curvature, by proper flat files or fine rasps, the place of the teeth is marked with a triangular file, and then the teeth themselves are cut out with a double saw, composed of two thin slips of tempered steel, such as the main-spring of a watch, notched with very fine sharp teeth. These slips are mounted in a wooden or iron stock or handle, in which they may be placed at different distances, to suit the width of the comb-teeth. A comb-maker, however, well provided in tools, has an assortment of double saws set at every ordinary with. The two slips of this saw have their teeth in different planes, so that when it begins to cut, the most prominent slip alone acts, and when the teeth of this one have fairly entered into the comb, the other parallel blade begins to saw. The workman, meanwhile, has fixed the plate of tortoise-shell or ivory between the flat jaws of two pieces of wood, like a vice made fast to a bench so that the comb intended to be cut is placed at an angle of 45° with the horizon. He now saws perpendicularly, forming two teeth at a time, proceeding truly in the direction of the first tracing.

A much better mode of making combs is to fix upon a shaft or arbor in a lathe a series of circular saws, with intervening brass washers or discs to keep them at suitable distances; to set in a frame like a vice, in front of these saws, the piece of ivory or horn to be cut; and to press it forward upon the saws at an angle of 45 degrees, by means of a regulated screw motion. When the teeth are thus cut, they are smoothed and polished with files, and by rubbing with pumice-stone and tripoli.

Mr. Bundy, of Camden Town, obtained a patent so long ago as 1796, for an apparatus of that kind, which had an additional arbor fitted with a series of circular saws, or rather files, for sharpening the points of the comb-teeth.

More recently, Mr. Lyne has invented a machine in which, by means of pressure, two combs are cut out at once with chisels from any tough material, such as horn or tortoise-shell, somewhat softened at the moment by the application of a heated iron to it. The piece of horn is made fast to a carriage, which is moved forward by means of a screw until it comes under the action of a ratchet-wheel, toothed upon a part of its circumference. The teeth of this wheel bring a lever into action, furnished with a chisel or knife, which cuts out a double comb from the flat piece, the teeth of which combs are opposite to each other. By this means, no part of the substance is lost, as in sawing out combs. The same carriage may be used, also, to bear a piece of ivory in the hard state toward a circular saw, on the principles above explained, with such precision, that from 80 to 100 teeth can be formed in the space of one inch by a proper disposition of the tool.

Bullocks' horns, after the tips are sawed off, are roasted in the flame of a wood fire, till they are sufficiently softened; when they are slit up, pressed in a machine between two iron plates, and then plunged into a trough of cold water, whereby they are hardened. A paste of quicklime, litharge, and water is used to stain the horn to resemble tortoise-shell. See Horn.

COMBINATION (*Combinaison*, Fr.; *Verbindung*, Germ.); a chemical term which denotes the intimate union of dissimilar particles of matter, into a homogeneous-looking compound, possessed of properties generally different from those of the separate constituents.

COMBUSTIBLE (Eng. and Fr.; *Brennstoff*, Germ.); any substance which, exposed in the air to a certain temperature, consumes spontaneously with the emission of heat and light. All such combustibles as are cheap enough for common use go under the name of Fuel; which see. Every combustible requires a peculiar pitch of temperature to be kindled, called its *accendible* point. Thus phosphorus, sulphur, hydrogen, carbureted hydrogen, carbon, each takes fire at successively higher heats.

COMBUSTIBLE SUGAR. When sugar is acted on by a mixture of nitric and sulphuric acids, a peculiar substance is produced, having a close resemblance to common resin, not only in its appearance and physical characters, but also in regard to its solubility in alcohol, ether, volatile oils, &c., and insolubility in water. This substance is, however, extremely inflammable and explosive, and possesses many of the properties ascribed to the celebrated Greek fire. Its affinity for alcohol and ether is so great that water will not remove these fluids from it. "Not having yet succeeded in producing with it any definite basic compound which would enable me to control my results, I have not attempted its analysis. The only purposes to which I have applied it are to the formation of fusees for shells, and to the preservation of gunpowder and pyrotechnical articles from damp and moisture. As a fusee, it is easily lighted, burns with great regularity, and appears absolutely incapable of being extinguished, circumstances which would render it of great use in ricochet practice. As a means of preventing the mischievous effect of damp and moisture on gunpowder it is of great value. The best mode of application is to plunge the gunpowder for a few seconds into an alcoholic or ethereal solution of the sugar compound, then withdraw it and allow it to dry at a gentle heat, say 120° Fahr., though there is no danger of an explosion at 212°. In this way the gunpowder is covered by a coat of varnish easy of ignition and insoluble in water, which cannot therefore penetrate to the gunpowder, the explosive nature of which is rather augmented than diminished by this treatment. An ethereal solution of gun-cotton does not answer so well for this purpose, nor is it so manageable. I have not ascertained how far this new substance is useful in retaining the edges of wounds in approximation, but its alcoholic solution merits a trial. The following is the method which I have found most successful in the manufacture of this compound:—

"Mix together sixteen parts of concentrated sulphuric acid and eight parts of nitric acid, spec. grav. 1·50; place the mixture in cold water, and when the temperature has fallen to 60° or less, stir in one part of finely-powdered sugar, which will become pasty in a few seconds, and is then to be removed and plunged in cold water, when more sugar may then be added to the acid mixture, and removed as before. The compound is to be washed in water and dissolved in alcohol, to which a solution of carbonate of potash must be added in excess, so as to precipitate the substance, and neutralize its uncombined acid. After careful washing with water, it is again to be dissolved in alcohol or ether, and cautiously evaporated to dryness by a steam heat, which must be continued for some time, so as entirely to expel the alcohol or ether. The residuary matter should have the transparency and general character of common rosin."—*Mr. L. Thompson.*

COMBUSTION (Eng. and Fr.: *Verbrennung*, Germ.) results in common cases from the mutual chemical reaction of the combustible, and the oxygen of the atmosphere, whereby a new compound is formed; the heat and light evolved being most probably produced by the rapid motions of the particles during the progress of this combination.

COMPOUND COLORS. If the effects of the coloring particles did not vary according to the combinations which they form, and the actions exercised upon them by the different substances present in a dyeing bath, we might determine with precision the shade which ought to result from the mixture of any two colors, or of the ingredients affording these colors separately. Though the chemical action of the mordants and of the liquor in the dye-bath often changes the result, yet theory may always predict them within a certain degree. It is not the color appropriate to the dye-stuffs which is to be considered as the constituent part of compound colors, but that which they must assume with a certain mordant and dye-bath. Our attention ought therefore to be directed principally to the operation of the chemical agents employed.

1. The mixture of blue and yellow dyes produces green. D'Ambourney, indeed, says that he has extracted a fast green from the fermented juice of the berries of the buckthorn (*rhamnus fragula*), but no dyer would trust to such a color.

2. The mixture of red and blue produces violet, purple, *columbine* (dove-color), pansy, amaranth, lilac, mallow, and a great many other shades, determined by the nature and tone of the red and blue dye-stuffs, as well as their relative proportions in the bath.

3. The mixture of red and yellow produces orange, *mordoré*, cinnamon, *coquelicot*, brick, capuchin; with the addition of blue, olives of various shades; and with duns instead of yellows, chestnut, snuff, musk, and other tints.

4. Blacks of the lighter kinds constitute grays; and, mixed with other colors, produce *marrone* (marroons), coffees, damascenes. For further details upon this subject, see Calico Printing, Dyeing, as also the individual colors in their alphabetical places.

CONCRETE. The name given by architects to a compact mass of pebbles, sand, and lime cemented together, in order to form the foundations of buildings. Semple says that the best proportions are 80 parts of pebbles, each about 7 or 8 ounces in weight, 40 parts sharp river sand, and 10 of good lime; the last is to be mixed with water to a thinnish consistence, and grouted in. It has been found that Thames ballast, as taken from the bed of the river, consists nearly of 2 parts of pebbles to 1 of sand, and therefore answers exceedingly well for making concrete; with from one seventh to one eighth part of lime. The best mode of making concrete, according to Mr. Godwin, is to mix the lime, previously ground, with the ballast in a dry state; sufficient water is now thrown over it to effect a perfect mixture, after which it should be turned over at least twice with shovels, or oftener; then put into barrows, and wheeled away for use instantly. It is generally found advisable to employ two sets of men to perform this operation, with three in each set; one man to fetch the water, &c., while the other two turn over the mixture to the second set, and they, repeating the process, turn over the concrete to the barrow-men. After being put into the barrows, it should at once be wheeled up planks, so raised as to give it a fall of some yards, and thrown into the foundation, by which means the particles are driven closer together, and greater solidity is given to the whole mass. Soon after being thrown in, the mixture is observed usually to be in commotion, and much heat is evolved with a copious emission of vapor. The barrow-load of concrete in the fall, spreading over the ground, will form generally a stratum of from 7 to 9 inches thick, which should be allowed to set before throwing in a second.

Another method of making concrete, is first to cover the foundation with a certain quantity of water, and then to throw in the dry mixture of ballast and lime. It is next turned and levelled with shovels; after which more water is pumped in, and the operation is repeated. The former method is undoubtedly preferable.

In some cases it has been found necessary to mix the ingredients in a pug-mill, as in mixing clay, &c. for bricks. For the preparation of a concrete foundation, as the hardening should be rapid. no more water should be used than is absolutely necessary to effect

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a perfect mixture of the ingredients. Hot water accelerates the induration. There is about one fifth of contraction in volume in the concrete, in reference to the bulk of its ingredients. To form a cubical yard of concrete, about 30 feet cube of ballast and 3½ feet cube of ground lime must be employed, with a sufficient quantity of water.

CONGELATION (Eng. and Fr.; *Gefrierung*, Germ.); the act of freezing liquids. Many means are supplied by chemistry for effecting or promoting this process, but they do not constitute any peculiar art or manufacture. See ICE-HOUSE.

COOLING OF FLUIDS. In Mr. Derosnes's method, the cooling agents employed are a current of atmospheric air, and warm water of the same or nearly the same temperature as that of the vapors which are to be operated upon.

***Fig.* 367** represents merely a diagram of the general features of an apparatus constructed upon the principles **proposed to be employed, which will serve to explain the** nature of this improvement.

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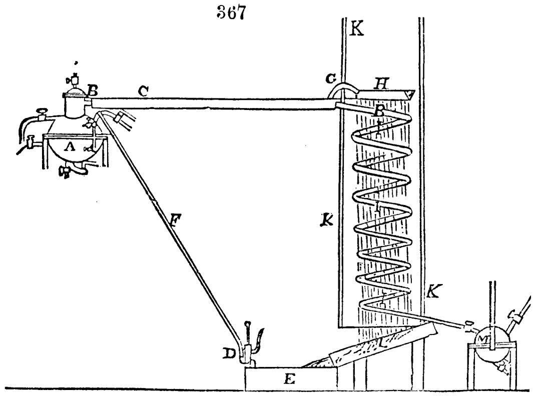

Let A be the source of the vapors, or the vessel, boiler, alembic, or closed pan that contains the liquid or sirup to be evaporated or concentrated. The pipe B, through which the vapor passes as it rises in the boiler, is surrounded by another tube C, of larger diameter, closed at both ends. A pump D, draws from the reservoir E, warm water, which water has been heated by its previous and continual passage through the apparatus in contact with the surface of the vapor pipes. This pump forces the water by the pipe F, into the annular space or chamber between the pipes B and C, in which chamber, by its immediate contact with the pipe B, it acquires the temperature of the vapors intended to be refrigerated. The pipe G conveys the water from the pipe C, into the annular colander or sieve H, which has a multitude of small holes pierced through its under part, and whence the warm water descends in the form of a continued shower of rain. To the end of the pipe B, a distiller's worm I I, is connected, which is placed beneath the colander H. The entire length of the worm-pipe should be bound round with linen or cotton cloth, as a conductor of the heat, which cloth will be continually moistened by the rain in its descent from the colander. As this water has been heated in passing along the tube C, the shower of rain descending from the colander will be at a higher temperature than that of the atmosphere, and, consequently, by heating the surrounding air as it descends, a considerable upward draft will be produced through the coils of the worm-pipe.

If the colander and the worm-pipe are enclosed within a chimney or upright tube, as K K, open at top and bottom, a current of ascending air will be produced within it by the descending shower of hot water, similar in effect to that which would be produced in a chimney communicating with a furnace, or to that of the burner of an argand lamp. Consequently, it will be perceived that in opposition to the descending rain, a strong upward current of air will blow through that part of the cylinder K K, which is beneath the colander. When the air first enters the lower aperture of the chimney or tube K, it is of the same temperature and moisture as the external atmosphere; but in its passage up the tube it meets with a warmer and damper atmosphere, caused by the heat given out from the hot fluid continually passing through the pipes, and by the hot shower of rain, and also by the steam evolved from the surfaces of the coils of the worm, which are continually wetted by the descending rain, the evaporation being considerably augmented by the cloth bound round the worm-pipe, retaining the water as it descends in drops from coil to coil.

The atmosphere within the tube being of a higher temperature than without, a current of air constantly ascends and escapes at the upper aperture K, and its place is supplied by fresh air from the surrounding atmosphere, entering the tube below. The fresh air thus admitted at the bottom of the tube, being cold and dry, will be suited to take up the heat and moisture within, because the water within the tube, being in a state of dispersion as rain, presents to the air many points, or a very extended surface, and also because it is of a higher temperature than the air; and, besides, cold dry air is continually renewed, and a source of warmth is furnished by the latent caloric to the steam, as fast as it is evolved. Thus a portion of the descending rain, or water, is evaporated, and the effect of this evaporation is to abstract caloric not only from the water held in contact with the coils of the worm-pipe by the cloth enveloping it, but also from the hot vapors which pass through the worm. This process of evaporation has, therefore, a cooling power, which is but slight in the lower part of the chimney or tube K, because the temperature of the water, or rain, and of the worm, at this part, are of a lower temperature; but its refrigerating power increases as it rises towards the colander, and there it acquires its maximum of intensity, so that at any point between the lower aperture of the cylinder and the colander the current of air is always a little cooler than the atmosphere of the region through which it passes (that is, as its maximum); and in passing this region of higher temperature, it is not only put in equilibrium of temperature, but also made to take up an additional quantity of aqueous vapors, which equalizes the new temperature it acquires with its capacity of saturation. The cooling caused by the evaporation acts in an incessant and progressive manner from the lower aperture of the cylinder to the under side of the colander; and this cooling not only acts as an agent of the evaporation which the current of air cools, but it refrigerates also, because it becomes warmed in abstracting caloric from the vapors or liquids passing through the worm; and this refrigeration acts also incessantly and progressively from the lower part of the tube or chimney to the colander.

The patentee states, in conclusion, that "the velocity or force of the current of air that passes through the chimney or tube K, can be accelerated by artificial means, either by conducting the air and vapor passing from the upper aperture of the cylinder into the chimney or flues of a furnace, or by means of a revolving, forcing, or exhausting fan, or ventilator, or any other contrivance which will produce an increased current of air, but which is not necessary to be particularly described, as I only wish to explain the principles of a simple apparatus, constructed in any convenient form; and I would remark, that the area of the lower aperture through which the air is introduced into the chimney or tube K, and also the area of the upper aperture, or that through which it passes to the atmosphere, should be in accordance with the effect intended to be obtained.

"It is further to be remarked, that in order to obtain from this apparatus the best effect, the velocity of the current of air must be itself a maximum; and as the speed or velocity of the current of air is owing to and determined by the excess of the temperature of the descending water, or rain, and of the coils of the worm to that of the exterior atmosphere, it ensues that the temperature of the water, or rain, must be a maximum. But this excess of temperature is a maximum only when the source of the rain is at the same temperature as the vapors to be condensed: if less warm, it would attract less air; or, if warmer, it would augment the temperature of the vapors intended to be condensed. Consequently, the shower of water employed in the tube K, as the agent for cooling, bestows its maximum of effect when it is as warm as the vapors to be condensed; therefore, I may express this proposition, viz., 'That in refrigerating with water, less of it may be expended when it is warm than when it is cold, and that the least quantity of water will be evaporated when it is as warm as the aqueous or spirituous vapors upon which it is to operate.'

"This proposition may appear strange, nevertheless it is conformable to the laws of nature; and appears only strange, because until now warm water has not been employed with currents of air for refrigerating.

"Hence it is necessary to raise the temperature of the water in the colander to the temperature of the vapors to be condensed: therefore, I cause the lukewarm water, pumped from the reservoir E, to circulate in the chamber C. In this circulation it also begins to act as a refrigerating medium, taking up a portion of heat from the vapors that pass through the pipe B, and afterwards it acts as a further condenser in the cylinder, in the way described. Finally, the portion of this water that is still in the fluid state, after having fallen down from coil to coil, arrives lukewarm to the inclined surface L, which conducts it into the reservoir E, from whence it is pumped up into the chamber C, as before described.

"The tube or chimney K may have more or less altitude; the higher it is the greater is the current produced. The force or velocity of the current of air can be governed by the areas of the introduction and exit apertures. If the cylinder rises only to the height of the sieve, the effect is much less than when it is prolonged beyond this height. I would further remark, that if the cylinder was removed, a slight effect might be produced, provided that a current of air be preserved in the cylindrical space limited by the coils of the worm, and also if the current was produced between the coils; or a central passage might be formed in an apparatus of another shape than that above described.

"I have only shown the application of the worm, because intending only to explain the principles of this method of condensing and refrigerating.

"The small quantity of water wasted in this manner of condensation, (that is, that portion passed off to the atmosphere in the form of vapors, at the upper aperture of the cylinder X), may be replaced by a small stream of cold water, which may be brought to the apparatus, and perhaps most conveniently introduced into the reservoir E, or into the chamber between the pipes B and C. When operating upon aqueous vapors, the waste of waters is always less in weight than that of the vapors liquefied. When this apparatus is applied to the purposes of distillation, the end of the worm should terminate in a vessel M, which is to receive the produce of the condensation. It will be seen that this improved process is applicable to various purposes, where condensation or refrigeration is required; for instance, in the boiling or concentration of sugar; to condensing and refrigerating distilled vapors, or steam, or saline liquids, either in vacuum or not; to cooling brewers' worts; and to the refrigeration of other liquors, or any other processes, when it may be required."

I have inserted the specification of this patent *verbatim.* M. Derosne has busied himself during a long life with a prodigious number of ingenious little contrivances for clarifying and boiling syrups, distillation, &c., but he has in this invention taken a bolder flight, having secured the exclusive privilege of condensing vapors, and cooling liquors, with hot water, in preference to cold. No man at all versant in the scientific doctrines, or the practical applications of caloric, will ever seek to meddle with his monopoly of such a scheme. He may find, perhaps, some needy coppersmith ready to espouse that or any other equally foolish project, provided a productive job can be made of it, against credulous customers.

For some rational methods of cooling liquors and condensing vapors, see REFRIGERATION, STILL, and SUGAR.

COPAL, a resin which exudes spontaneously from two trees, the *Rhus copallinum*, and the *Elæocarpus copalifer*, the first of which grows in America, and the second in the East Indies. A third species of copal-tree grows on the coasts of Guinea, especially on the banks of some rivers, among whose sands the resin is found. It occurs in lumps of various sizes and of various shades of color, from the palest greenish yellow to darkish brown. I found its specific gravity to vary in different specimens from 1·059 to 1·071, being intermediate in density between its two kindred resins, animé and amber. Some rate its specific gravity so high as 1·139, which I should think one of the errors with which chemical compilations teem. Copal is too hard to be scratched by the nail, whence the excellence of its varnish. It has a conchoidal fracture, and is without smell or taste. When exposed to heat in a glass retort over a spirit lamp, it readily melts into a liquid, which being further heated boils with explosive jets. A viscid, oily-looking matter then distils over. After continuing the process for some time, no succinic acid is found in the receiver, but the copal blackens in the retort. Anhydrous alcohol boiled upon it causes it to swell, and transforms it by degrees into an elastic, viscid substance. It is not soluble in alcohol of 0·825 at the boiling point, as I have ascertained. Copal dissolves in ether, and this ethereous solution may be mixed with alcohol without decomposition. Caoutchoucine acts very slightly upon it by my experiments, even at the boiling temperature of this very volatile fluid; but a mixture of it with alcohol of 0·825, in equal parts, dissolves it very rapidly in the cold into a perfectly liquid varnish. Alcohol holding camphor in solution also dissolves it, but not nearly so well as the last solvent. According to Unverdorben, copal may be completely dissolved by digesting one part of it for 24 hours with one part and a half of alcohol (probably anhydrous), because that portion of copal which is insoluble in alcohol dissolves in a very concentrated solution of the soluble portion. Oil of petroleum and turpentine dissolve only 1 or 2 per cent. of raw copal. By particular management, indeed, oil of turpentine may be combined with copal, as we shall describe under the article VARNISH.

Fused copal possesses different properties from the substance in its solid state; for it then may be made to combine both with alcohol and oil of turpentine.

Unverdorben has extracted from the copal of Africa five different kinds of resin, none of which has, however, been applied to any use in the arts.

The ultimate constituents of copal by my analysis are, carbon 79·87, hydrogen 9·00, oxygen 11·1; being of hydrogen 7·6 in excess above the quantity necessary to form water with the oxygen.

Much information has been received from various sources concerning this somewhat ill-understood product of late years. It is now known that there are three different kinds of copal in commerce, but nothing is known of their distinguishing characteristics. We have East Indian and West Indian copal, and, under the latter name, two very different substances. The East Indian, called also African, is more colorless, soft, and transparent, than the others; it forms a fine surface, and when heated emits an agreeable odor. It furnishes the finest varnish. Fresh essence of turpentine dissolves it completely, but not old. Essence digested upon sulphur will dissolve double its own weight, without letting any fall. Fresh rectified oil of rosemary will dissolve it in any proportion, but if the oil is thickened by age it serves only to swell this copal.

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When cautiously melted, it may be then dissolved in good essence of turpentine in any proportion, producing a fine varnish, of little color.

A good varnish may be made by dissolving 1 part of copal, 1 of essence of rosemary, with from 2 to 3 of pure alcohol. This varnish should be applied hot, and when cold becomes very hard and durable.

The West India species, or American, comes to us, not in lumps of a globular form, but in small flat fragments, which are hard, rough, and without taste or smell. It is usually yellow, and never colorless like the other. Insects are very rarely found in it. It comes from the Antilles, Mexico, and North America. It will not dissolve in essence of rosemary.

The third kind of copal, known also as West Indian, was formerly sold as a product of the East Indies. It is found in fragments of a concavo-convex form, the outer covering of which appears to have been removed. It contains many insects. When rubbed it emits an aromatic odor. It gives out much ethereous and empyreumatic oil when melted. It forms a soft varnish, which dries slowly.

Fusel oil, or amyle spirit, has been lately used as a solvent of the hard copal; but it does not dry into a very solid varnish.

Annexed is an account of the import of animé and copal, in the undermentioned years:—

		1841.	1842.	1843.	1844.
Quantities imported	cwts.	—	3336	3359	6493
Quantities exported	cwts.	—	1403	1508	2467
Retained for consumption	cwts.	—	2091	2085	2770
Nett revenue	£	535	295	117	157

COPPER is one of the metals most anciently known. It was named from the island of Cyprus, where it was extensively mined and smelted by the Greeks. It has a reddish brown color inclining to yellow; a faint but nauseous and rather disagreeable taste; and when rubbed between the fingers it imparts a smell somewhat analogous to its taste. Its specific gravity is from 8·8 to 8·9. It is much more malleable than it is ductile; so that far finer leaves may be obtained from it than wire. It melts at the 27th degree of Wedgewood's pyrometer, and at a higher temperature it evaporates in fumes which tinge the flame of a bluish green. By exposure to heat with access of air, it is rapidly converted into black scales of peroxide. In tenacity it yields to iron; but surpasses gold, silver, and platinum, considerably in this respect.

In mineralogy, the genus copper includes about 13 different species, and each of these contains a great many varieties. These ores do not possess any one general exterior character by which they can be recognised; but they are readily distinguished by chemical re-agents. Water of ammonia digested upon any of the cupreous ore in a pulverized state, after they have been calcined either alone or with nitre, assumes an intense blue color, indicative of copper. The richest of the ordinary ores appear under two aspects: the first class has a metallic lustre, a copper red, brass yellow, iron gray, or blackish gray color, sometimes inclining to blue; the second is without metallic appearance, has a red color, verging upon purple, blue, or green, the last tint being the most usual. Few copper ores are to be met with, indeed, which do not betray the presence of this metal by more or less of a greenish film.

Dr Scherer, of Freyberg, has arranged the ores of copper as follows:—

	Symbol.	Copper in 100.
1.	Copperglanz (*Kupferglaserz*) Cu_2S	79·7
2.	Kupferkies, Copper pyrites, Cu_2S, Fe_2S_3	34·8
3.	Buntkupfererz 3 Cu_2S, Fe_2S_3	55·7
4.	Fahlerz 4 (Cu_2S, FeS, ZnS, AgS ($Sb\ S_3\ As\ S_3$)	14—41
5.	Rothkupfererz Cu_2O	88·5
6.	Malachit 2 CuO, $CO_2 + HO$	57·4
7.	Kupferlasur (2 (CuO, CO_2) $+ CuO . HO$	55·3

Both Fahlerz and Buntkupfererz vary greatly in their proportion of copper. Fahlerz is very difficult to convert into pure copper by smelting, on account of the presence of antimony and arsenic in it. Kupferglanz is a disulphuret of copper. Buntkupfererz is purple or variegated copper ore. Rothkupfererz is the orange or red oxide of copper. Kuferlasur is blue carbonate of copper.

Pure copper may be obtained in the solid state either by the reduction of the powder of the pure oxide by a stream of hydrogen gas passed over it in an ignited tube, or by the galvanoplastic process. See ELECTRO-METALLURGY, or ELECTROTYPIE.

1. *Native Copper* occurs in crystals, branches, and filaments, its most common locality being in primitive rocks. It is found abundantly in Siberia, at the mines of Tourinski, in those of Hungary, of Fundo-Moldavi in Gallicia, of Fahlun in Sweden.

of Cornwall, &c. The gangues of native copper are granite, gneiss, mica-slate, clay slate, quartz, carbonate or fluate of lime, sulphate of barytes, &c. The most remarkable masses of native copper hitherto observed were—first, one in Brazil, 14 leagues from Basa, which weighed 2616 pounds; and secondly, another which Dr. Francis-le-Baron discovered in America to the south of Lake Superior. It was nearly 15 feet in circumference.

2. *Sulphuret of Copper, the vitreous ore of Brochant.* The texture of this ore is compact; its fracture, conchoidal, surface sometimes dull; color, iron black or lead gray, often bluish, iridescent, or reddish from a mixture of protoxyde. It is easily melted even by the heat of a candle; but more difficult of reduction than protoxyde. This ore yields to the knife, assuming a metallic lustre when cut. Its density varies from 4·8 to 5·34. Its composition, according to Klaproth, is 78·5 copper, 18·5 sulphur, with a little iron and silica. Its equivalent constitution by theory is 80 copper + 20 sulphur = 100; whence 78·5 of metal should be associated with 19·6 of sulphur. This ore is therefore one of the richest ores, and forms very powerful veins, which likewise contain some orange protoxyde. It is to be found in all considerable copper districts; in Siberia, Saxony, Sweden, and especially Cornwall, where the finest crystals occur.

3. *Copper Pyrites* resembles in its metallic yellow hue, sulphuret of iron; but the latter is less pale, harder, and strikes fire more easily with steel. It presents the most lively rainbow colors. Its specific gravity is 4·3. It contains generally a good deal of iron, as the following analysis will show: copper 30, sulphur 37, iron 33, in 100 parts. According to Hisinger, the Swedish pyrites contains 63 of copper, 12 of iron, and 25 of sulphur. These ores occur in primitive and transition districts in vast masses and powerful veins; and are commonly accompanied with gray copper, sulphuret of iron, sparry iron sulphurets of lead, and zinc.

4. *Gray Copper* has a steel gray color, more or less deep, either shining or dull; fracture uneven; a distinct metallic lustre; difficult of fusion at the blowpipe; it communicates to glass of borax a yellowish-red color. Its density in crystals is 4·86. Its composition is very variable; consisting essentially of copper, iron, antimony, and sulphur. The exploration of this ore is profitable, in consequence of the silver which it frequently contains. It occurs in primitive mountains; and is often accompanied with red silver ore, copper pyrites, and crystallized quartz.

5. *Protoxyde of Copper*, or *red oxyde of Copper*: its color is a deep red, sometimes very lively, especially when bruised. It is friable, difficult of fusion at the blowpipe, reducible on burning charcoal, soluble with effervescence in nitric acid, forming a green liquid. Its constitution, when pure, is 88·9 copper + 11·1 oxygen = 100.

6. *Black oxyde of Copper* is of a velvet black, inclining sometimes to brown or blue; and it acquires the metallic lustre on being rubbed. It is infusible at the blowpipe. Its composition is, copper 80 + oxygen 20; being a true peroxyde.

7. *Hydrosilicate of Copper* consists essentially of oxyde of copper, silica, and water. Its color is green; and its fracture is conchoidal with a resinous lustre, like most minerals which contain water. Its specific gravity is 2·73. It is infusible at the blowpipe alone, but it melts easily with borax.

8. *Dioptase Copper*, or *Emerald Malachite;* a beautiful but rare cupreous mineral, consisting of oxyde of copper, carbonate of lime, silica, and water in varying proportions.

9. *Carbonate of Copper, Malachite*, is of a blue or green color. It occurs often in beautiful crystals.

10. *Sulphate of Copper, Blue Vitriol*, similar to the artificial salt of the laboratory The blue water which flows from certain copper mines is a solution of this salt. The copper is easily procured in the metallic state by plunging pieces of iron into it.

11. *Phosphate of Copper* is of an emerald green, or verdigris color, with some spots of black. It presents fibrous or tuberculous masses with a silky lustre in the fracture. It dissolves in nitric acid without effervescence, forming a blue liquid; melts at the blowpipe, and is reducible upon charcoal, with the aid of a little grease, into a metallic globule. Its powder does not color flame green, like the powder of muriate of copper.

12. *Muriate of Copper* is green of various shades; its powder imparts to flame a remarkable blue and green color. It dissolves in nitric acid without effervescence; and is easily reduced before the blowpipe. Its density is 3·5. By Klaproth's analysis, it consists of oxyde of copper 73, muriatic acid 10, water 17.

13. *Arseniate of Copper.* It occurs in beautiful blue crystals. Before the blowpipe it melts, exhaling fumes of a garlic odor, and it affords metallic globules when in contact with charcoal. See more upon the ores at the end of this article.

In the article Metallurgy, I have described the mode of working certain copper mines; and shall content myself here with giving a brief account of two cupreous formations, interesting in a geological point of view; that of the copper slate of Mansfeldt, and of the copper veins of Cornwall.

The curious strata of bituminous schist in the first of these localities, are among the most ancient of any which contain the exuviæ of organized bodies not testaceous. From among their tabular slabs the vast multitudes of fossil fish were extracted, which have rendered the cantons of Mansfeldt, Eisleben, Ilmenau, and other places in Thuringia and Voigtland so celebrated. Many of the fish are transformed into copper pyrites. Here also, have been found the fossil remains of the lizard family, called *Monitors*.

Such is the influence of a wise administration upon the prosperity of mines, that the thin layer of slate in this formation, of which 100 pounds commonly contain but one pound and a half of copper, occasionally argentiferous, has been for several centuries the object of smelting works of the greatest importance to the territory of Mansfeldt and the adjoining country.

The frequent derangements which this metallic deposite experiences, led skilful directors of the under-ground operations at an early period to study the order of superposition of the accompanying rocks. From their observations, there resulted a system of facts which have served to guide miners, not only in the country of Mansfeldt, but over a great portion of Germany, and in several other countries where the same series of rocks, forming the immediate envelope of the cupreous schists, were found to occur in the same order of superposition.

Of the English copper works.—The deposites of copper in Cornwall occur always as veins in granite, or in the schistose rocks which surround and cover it; and hence, the Cornish miners work mostly in the granite or greenish clay slate; the former of which they call *growan*, the latter *killas*. But tin is sometimes disseminated in small veins in porphyry or *elvan*, which itself forms great veins in the above rocks. No stratification has been observed in Cornwall.

The copper veins are abundant in the killas and rare in the granite; but most numerous near the line of junction of the two rocks. The different kinds of mineral veins in Cornwall may be classed as follows:—

1. Veins of elvan; elvan courses, or elvan channels.
2. Tin veins, or tin *lodes;* the latter word being used by the Cornish miners to signify a vein rich in ore, and the word *course*, to signify a barren vein.
3. Copper veins running east and west; east and west copper lodes.
4. Second system of copper veins, or *contra* copper lodes.
5. Crossing veins; cross courses.
6. Modern copper veins; more recent copper lodes.
7. Clay veins; of which there are two sets, the more ancient, called *Cross-Fluckans;* and the more modern, called *Slides*.

There are therefore three systems of copper veins in Cornwall; of which the first is considered to be the most ancient, because it is always traversed by the two others, and because, on the contrary, it never cuts them off. The width of these veins does not exceed 6 feet, though occasional enlargements to the extent of 12 feet sometimes take place. Their length is unknown, but the one explored in the *United Mines* has been traced over an extent of seven miles. The gangue of these veins is generally quartz, either pure, or mixed with green particles analogous to chlorite. They contain iron pyrites, blende, sulphuret, and several other compounds of copper, such as the carbonate, phosphate, arseniate, muriate, &c. The most part of the copper veins are accompanied with small argillaceous veins, called by the miners *fluckan of the lode.* These are often found upon both sides of the vein, so as to form cheeks or *salebandes.*

When two veins intersect each other, the direction of the one thrown out becomes an object of interest to the miner and geologist. In Saxony it is regarded as a general fact that the rejected portion is always to the side of the *obtuse angle;* this also holds generally in Cornwall, and the more obtuse the angle of incidence, the more considerable the out-throw.

The great copper vein of *Carharack*, in the parish of Gwenap, is a most instructive example of intersection. The power of this vein is 8 feet; it runs nearly from east to west, and dips toward the north at an inclination of 2 feet in a fathom. Its upper part is in the killas, its lower part in the granite. The vein has suffered two intersections; the first results from encountering the vein called *Steven's fluckan*, which runs from north-east to south-west, throwing it out several fathoms. The second has been caused by another vein, almost at right angles to the first, and which has driven it 20 fathoms out to the right side. The fall of the vein occurs, therefore, in one case to the right, and in the other to the left; but in both instances, it is to the side of the obtuse angle. This disposition is very singular; for one portion of the vein appears to have ascended, while another has sunk.

The mining works in the copper veins are carried on by reverse steps; see MINES The grand shafts for drainage and extraction are vertical, and open upon the roof side of the vein, traversing it to a certain depth. These pits are sunk to the lowest point of the exploration; and, in proportion as the workings descend, by means of excavations in the vein, the pits are deepened and put into communication toward their bottom with each new gallery of elongation, by means of transverse galleries. At present, the main shafts are fully 160 fathoms deep. Their horizontal section is oblong, and is divided into two compartments; the one destined for extraction, the other for the pumps. Their timbering has nothing remarkable, but is executed with every attention to economy, the whole wood employed in these mines being brought from Norway.

The descent of the workmen is effected by inclined shafts scooped out of the vein; the ladders are slightly inclined; they are interrupted every 10 fathoms by floors; the steps are made of iron, and, to prevent them from turning under the foot, the form of a miner's punch or jumper has been given them, the one end being round, and the other being wedge-shaped.

The ore is raised either by means of horse-gins, or by steam-engine power, most frequently of high pressure. I shall take the *Consolidated Mines* as an example.

The draining, which is one of the most considerable sources of expense, both from the quantity of water, and from the depth of the mine, is executed by means of sucking and forcing pumps, the whole piston-rods of which, 120 feet long, are attached to a main-rod suspended at the extremity of the working beam of a steam-engine.

On this mine three steam-engines are erected of very great power, for the purpose of drainage; the one called the *Maria* engine is of the first-rate force, and most improved construction. The cylinder is 90 inches in internal diameter, and the length of the stroke is 9 feet 11 inches. It works single stroke, and is incased in a coating of bricks to prevent dissipation of the heat. The vapor is admitted at the upper end of the cylinder during the commencement of the fall of the piston, at a pressure capable of forming an equilibrium with a column of 60 inches of mercury. The introduction of the steam ceases whenever the piston has descended through a certain space, which may be increased or diminished at pleasure. During the remainder of the descent the piston is pressed merely by this vapor in its progressive expansion, while the under side of the piston communicates with the condenser. It ascends by the counterweight at the pump end of the working beam. Hence, it is only during the descent of the piston that the effective stroke is exerted. Frequently the steam is admitted only during the sixth part of the course of the piston, or 18 inches. In this way the power of the engine is proportioned to the work to be done; that is, to the body of water to be raised. The *maximum* force of the above engine is about 310 horses; though it is often made to act with only one third of this power.

The copper mines of the Isle of Anglesey, those of North Wales, of Westmoreland, the adjacent parts of Lancashire and Cumberland, of the south west of Scotland, of the Isle of Man, and of the south east of Ireland, occur also in primitive or transition rocks. The ores lie sometimes in masses, but more frequently in veins. The mine of Ecton in Staffordshire, and that of Cross-gill burn, near Alston-moor in Cumberland, occur in transition or metalliferous limestone.

The copper ores extracted both from the granitic and schistose localities, as well as from the calcareous, are uniformly copper pyrites more or less mixed with iron pyrites; the red oxyde, carbonate, arseniate, phosphate, and muriate of copper, are very rare in these districts.

The working of copper in the Isle of Anglesey may be traced to a very remote era. It appears that the Romans were acquainted with the Hamlet mine near Holyhead; but it was worked with little activity till about 70 years ago. This metalliferous deposite lies in a greenish clay slate, passing into talc slate; a rock associated with serpentine and euphotide (*gabbro* of Von Buch). The veins of copper are from one to two yards thick, and they converge towards a point where their union forms a considerable mass of ore. On this mass the mine was first pierced by an open excavation, which is now upwards of 300 feet deep, and appears from above like a vast funnel. Galleries are formed at different levels upon the flank of the excavation to follow the several small veins, which run in all directions, and diverge from a common centre like so many radii. The ore receives in these galleries a kind of sorting, and is raised by means of hand windlasses to the summit of a hill, where it is cleaned by breaking and riddling.

The water is so scanty in this mine that it is pumped up by a six-horse steam-engine. A great proportion of it is charged with sulphate of copper. It is conveyed into reservoirs containing pieces of old iron; the sulphate is thus decomposed into copper of cementation. The Anglesea ore is poor, yielding only from 2 to 3 *per cent.* of copper: a portion of its sulphur is collected in roasting the ore.

Mechanical preparation of the copper ores in Cornwall.—The ore receives a first sorting, either within the mine itself, or at its mouth, the object of which is to separate all the pieces larger than a walnut. These are then reduced by the hammer to a smaller size; after which the whole are sorted into four lots, according to their relative richness. The fragments of poor ore are pounded in the stamps so that the metallic portion may be separated by washing.

The rich ore is broken into small bits, of the size of a nut, with a flat beater, formed of a piece of iron 6 inches square and 1 inch thick, adapted to a wooden handle. The ore to be broken is placed upon plates of cast-iron; each about 16 inches square and 1½ inch thick. These iron plates are set towards the edge of a small mound about a yard high, constructed with dry stones rammed with earth. The upper surface of this mound is a little inclined from behind forwards. The work is performed by women, each furnished with a beater; the ore is placed in front of them beyond the plates; they break it, and strew it at their feet, whence it is lifted and disposed of to the smelting-houses.

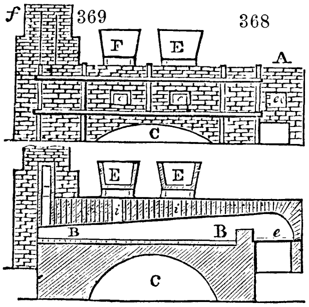
Inferior ores, containing a notable proportion of stony matters, are also broken with the beater, and the rich parts are separated by riddling and washing from the useless matters.

The smaller ore is washed on a sieve by shaking it in a stream of water, which carries away the lighter stony pieces, and leaves the denser metalliferous. They are then sorted by hand. Thus by beating, stamping, and riddling in water, the stony substances are in a great measure separated. The finer ground matter is washed on a plane table, over which a current of water is made to flow. Finally, the ore nearly fine is put into a large tub with water, and briskly stirred about with a shovel, after which it settles in the order of richness, the pure metallic ore being nearest the bottom. The stamps used for copper ore in Cornwall are the same as those used for tin ores, of which we shall speak in treating of the latter metal, as well as of the boxes for washing the fine powder or *slime*. These, in fact, do not differ essentially from the stamping mills and washing apparatus described in the article METALLURGY. Crushing rolls are of late years much employed. See LEAD and TIN.

Cornwall being destitute of coal, the whole copper ore which this county produces is sent for smelting to South Wales. Here are 15 copper works upon the Swansea and Neath, which pursue a nearly uniform and much improved process, consisting in a series of calcinations, fusions, and roastings, executed upon the ores and the matters resulting from them.

The furnaces are of the reverberatory construction; they vary in their dimensions and in the number of their openings, according to the operations for which they were intended. There are 5 of them:—1. The calcining furnace or calciner; 2. The melting furnace; 3. The roasting furnace or roaster; 4. The refining furnace; 5. The heating or igniting furnace.

1. The calcining furnace rests upon a vault, C, into which the ore is raked down after being calcined; it is built of bricks, and bound with iron bars, as shown in the elevation, *fig.* 368. The hearth, B′B, *figs.* 368 and 370, is placed upon a level with the lower horizontal binding bar, and has nearly the form of an ellipse, truncated at the two extremities of its great axis. It is horizontal, bedded with fire-bricks set on edge, so that it may be removed and repaired without disturbing the arch upon which it reposes. Holes, not visible in the figure, are left in the shelves before each door, *c c*, through which the roasted ore is let fall into the subjacent vault. The dimensions of the hearth B B are immense, being from 17 to 19 feet in length, and from 14 to 16 in breadth. The fire-place, A, *fig.* 370, is from 4½ to 5 feet long, and 3 feet wide. The bridge or low wall, *b*, *fig.* 374, which separates the fire-place from the hearth, is 2 feet thick; and in Mr. Vivian's smelting-works is hollow, as shown in the figure, and communicates at its two ends with the atmosphere, in order to conduct a supply of fresh air to the hearth of the furnace. This judicious contrivance will be described in explaining the *roasting* operation. The arched roof of the furnace slopes down from the bridge to the beginning of the chimney, *f*, *figs.* 369, 370, its height above the hearth being at the first point about 26 inches, and from 8 to 12 at the second.



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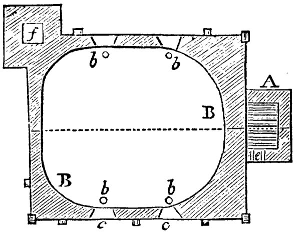

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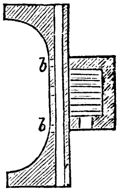

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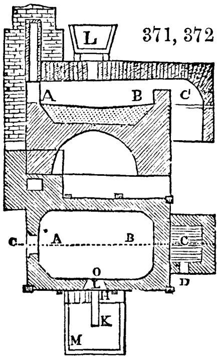
Such great calcining furnaces have 4 or 5 doors, *c c c c*, *fig.* 370, one for the fire-place, as shown at the right hand in *fig.* 369, and 3 or 4 others for working the ore upon the reverberatory hearth. If there be 3, 2 of them are placed between the vertical binding bars upon one side, and a third upon the opposite side of the furnace; if there be 4, 2 are placed upon each side, facing one another. These openings are 12 inches square, and are bound with iron frames. The chimney is about 22 feet high, and is placed at one angle of the hearth, as at *f*, *fig.* 370, being joined by an inclined flue to the furnace.

For charging it with ore there are usually placed above the upper part of the vault 2 hoppers, E E, in a line with the doors; they are formed of 4 plates of iron, supported in an iron frame. Beneath each of them there is an orifice for letting the ore down into the hearth.

These furnaces serve for calcining the ore, and the *matts* or *crude coppers:* for the latter purpose, indeed, furnaces of two stories are sometimes employed, as represented in *fig.* 373. The dimensions of each floor in this case are a little less than the preceding. Two doors, *c c*, correspond to each hearth, and the workmen, while employed at the upper story, stand upon a raised moveable platform.


371, 372

2. *Melting furnace*, *figs.* 371 and 372. The form of the hearth is also elliptical, but the dimensions are smaller than in the calcining furnace. The length does not exceed 11 or 11½ feet, and the breadth varies from 7 to 8. The fire-place is however larger in proportion, its length being from 3½ feet to 4, and its breadth from 3 to 3½; this size being requisite to produce the higher temperature of this furnace. It has fewer openings, there being commonly three; one to the fire-place at D, a second one, O, in the side, kept generally shut, and used only when incrustations need to be scraped off the hearth, or when the furnace is to be entered for repairs; and the third or working-door, G, placed on the front of the furnace beneath the chimney. Through it the scoriæ are raked out, and the melted matters are stirred and puddled, &c.

The hearth is bedded with infusible sand, and slopes slightly towards the side door, to facilitate the discharge of the metal. Above this door there is a hole in the wall of the chimney (*fig.* 372) for letting the metal escape. An iron gutter, O, leads it into a pit, K, bottomed with an iron receiving-pot, which may be lifted out by a crane. The pit M is filled with water, and the metal becomes granulated as it falls into the receiver. The melting furnaces are surmounted by a hopper, L, as shown in *fig.* 371.

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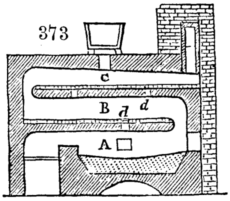

Melting furnaces are sometimes used also for calcination. There are some such near Swansea, which serve this double purpose; they are composed of 3 floors (*fig.* 373.) The floor A is destined for melting the calcined ore; the other two, B C, serve for calcination. The heat being less powerful, upon the upper sole C, the ore gets dried upon it, and begins to be calcined — a process completed on the next floor. Square holes, *d*, left in the hearths B and C, put them in communication with each other, and with the lower one A; these perforations are shut during the operation by a sheet of iron, removeable at pleasure.

The hearths *b* and *c* are made of bricks; they are horizonal at top and slightly vaulted beneath; they are 2 bricks thick, and their dimensions are larger than those of the inferior hearths, as they extend above the fire-place. On the floors destined for calcination the furnace has two doors on one of its sides: on the lower story there are also two; but they are differently collocated. The first, being in the front of the furnace, serves for drawing off the scoriæ, for working the metal, &c.; and the second, upon the side, admits workmen to make necessary repairs. Below this door the discharge or tap-hole A is placed, which communicates by a cast-iron gutter with a pit filled with water. The dimensions of this furnace in length and breadth are nearly the same as those of the melting furnace above described; the total height is nearly 12 feet. It is charged by means of one or two hoppers.

3. *Roasting furnace.* — The furnaces employed for this purpose are in general analogous to the calcining ones; but in the smelting works of Hafod, the property of Messrs. Vivian, these furnaces, alluded to above, present a peculiar construction, for the purpose of introducing a continuous current of air upon the metal, in order to facilitate its oxydizement. This process was originally invented by Mr. Sheffield, who disposed of his patent right to Messrs. Vivian.

The air is admitted by a channel, *c c*, through the middle of the fire-bridge, *fig.* 374, and extending all its length; it communicates with the atmosphere at its two ends *c c;* square holes, *b b*, left at right angles to this channel, conduct the air into the fur nace. This very simple construction produces a powerful effect in the roasting operation. It not only promotes the oxydizement of the metals, but burns the smoke, and assists in the vaporization of the sulphur; while by keeping the bridge cool it preserves it from wasting, and secures uniformity of temperature to the hearth.

4. *Refining furnace.* — In this, as in the melting furnace, the sole slopes towards the door in front, instead of towards the side doors, because in the refining furnace the copper collects into a cavity formed in the hearth towards the front door, from which it is lifted out by ladles; whereas, in the melting furnaces, the metal is run out by a tap-hole in the side. The hearth sole is laid with sand; but the roof is higher than in the melting furnace, being from 32 to 36 inches. If the top arch were too much depressed, there might be produced upon the surface of the metal a layer of oxyde very prejudicial to the quality of the copper. When the metal in that case is run out, its surface solidifies and cracks, while the melted copper beneath breaks through and spreads irregularly over the cake. This accident, called the *rising of the copper*, hinders it from being laminated, and requires it to be exposed to a fresh refining process, when lead must be added to dissolve the oxyde of copper. This is the only occasion upon which the addition of lead is proper in refining copper. When the metal to be refined is mixed with others, particularly with tin, as in extracting copper from old bells, then very wide furnaces must be employed, to expose the metallic bath upon a great surface, and in a thin stratum, to the oxydizing action of the air.

The door G, *fig.* 372, upon the side of the refining furnace, is very large, and is shut with a framed brick door, balanced by a counter-weight. This door being open during the refining process, the heat is stronger at B than at A, (*figs.* 371, 372.)

5. *Heating furnaces*, being destined to heat the pigs or bars of copper to be laminated, as well as the copper sheets themselves, are made much longer in proportion to their breadth. Their hearth is horizontal, the vault not much depressed; they have only one door, placed upon the side, but which extends nearly the whole length of the furnace; this door may be raised by means of a counter-weight, in the same way as in the furnaces for the fabrication of sheet-iron and brass.

Series of operations to which the ore is subjected. — The ores which are smelted in the Swansea works are cupreous pyrites, more or less mingled with *gangue* (vein-stone). The pyrites is composed of nearly equal proportions of sulphuret of copper and sulphuret of iron.

The earthy matters which accompany the pyrites are usually silicious, though in some mines the metalliferous deposite is mixed with clay or fluate of lime. Along with these substances, pretty uniformly distributed, tin and arsenical pyrites occur occasionally with the copper; and though these two metals are not chemically combined, yet they cannot be separated entirely in the mechanical preparations. The constituent parts of the ore prepared for smelting are, therefore, copper, iron, sulphur, with tin, arsenic, and earthy matters in some cases. The different ores are mixed in such proportions that the average metallic contents may amount to 8½ per cent. The smelting process consists in alternate roastings and fusions. The following description of it is chiefly taken from an excellent paper, published by John Vivian, Esq., in the Annals of Philosophy for 1823.

In the roasting operation the volatile substances are disengaged mostly in the gaseous state, while the metals that possess a strong affinity for oxygen become oxydized. In the fusion the earthy substances combine with these oxydes, and form glassy scoriæ or slags which float upon the surface of the melted metal.

These calcinations and fusions take place in the following order: —

1. Calcination of the ore. 2. Melting of the calcined ore. 3. Calcination of the coarse metal. 4. Melting of the calcined coarse metal. 5. Calcination of the fine metal (second matt). 6. Melting of the calcined fine metal. 7. Roasting of the coarse copper. In some smelting works, this roasting is repeated four times; in which case a calcination and a melting are omitted. In the Havod works, however, the same saving is made without increasing the number of roastings. 8. Refining or toughening the copper.

Besides these operations, which constitute the treatment of copper properly speaking, two others are sometimes performed, in which only the scoriæ are melted. These may be designated by the letters *a* and *b*. *a* is the re-melting of the portion of the scoriæ of the second process, which contain some metallic granulations. *b* is a particular melting of the scoriæ of the fourth operation. This fusion is intended to concentrate the particles of copper in the scoriæ, and is not practised in all smelting works.

First operation. Calcination of the ore. — The different ores, on arriving from Cornwall and other districts where they are mined, are discharged in continuous cargoes at the smelting works, in such a way, that by taking out a portion from several heaps at a time, a tolerably uniform mixture of ores is obtained; which is very essential in a foundry, because, the ores being different in qualities and contents, they act as fluxes upon each other. The ore thus mixed is transported to the works in wooden measures that hold a hundred-weight. The workmen intrusted with the calcination convey the ore into the hoppers of the calcining furnace, whence it falls into the hearth; other workmen spread it uniformly on the surface by iron rakes. The charge of a furnace is from three tons to three tons and a half. Fire is applied and gradually increased, till, towards the end of the operation, the temperature be as high as the ore can support without melting or agglutinating. To prevent this running together, and to aid the extrication of the sulphur, the surfaces are renewed, by stirring up the ore at the end of every hour. The calcination is usually completed at the end of 12 hours, when the ore is tumbled into the arch under the sole of the furnace. Whenever the ore is cold enough to be moved, it is taken out of the arch, and conveyed to the calcined heap.

The ore in this process hardly changes weight, having gained in oxydizement nearly as much as it has lost in sulphur and arsenic; and if the roasting has been rightly managed, the ore is in a black powder, owing to the oxyde of iron present.

Second operation. Fusion of the calcined ore.—The calcined ore is likewise given to the melters in measures containing a hundred weight. They toss it into hoppers, and after it has fallen on the hearth, they spread it uniformly. They then let down the door, and lute it tightly. In this fusion there are added about 2 cwt. of scoriæ proceeding from the melting of the calcined matt, to be afterwards described. The object of this addition is not only to extract the copper that these scoriæ may contain, but especially to increase the fusibility of the mixture. Sometimes also, when the composition of the ore requires it, lime, sand, or fluor spar is added; and particularly the last fluxing article.

The furnace being charged, fire is applied, and the sole care of the founder is to keep up the heat so as to have a perfect fusion; the workman then opens the door, and stirs about the liquid mass to complete the separation of the metal (or rather of the matt) from the scoriæ, as well as to hinder the melted matter from sticking to the sole. The furnace being ready, that is, the fusion being perfect, the founder takes out the scoriæ by the front door, by means of a rake. When the matt is thus freed from the scoriæ, a second charge of calcined ore is then introduced to increase the metallic bath; which second fusion is executed like the first. In this way, new charges of roasted ore are put in till the matt collected on the hearth rises to a level with the door-way, which happens commonly after the third charge. The tap hole is now opened; the matt flows out into the pit filled with water, where it is granulated during its immersion; and it collects in the pan placed at the bottom. The granulated matt is next conveyed into the matt warehouse. The oxydation with which the grains get covered by the action of the water does not allow the proper color of the matt or coarse metal to be distinguished; but in the bits which stick in the gutter, it is seen to be of a steel gray. Its fracture is compact, and its lustre metallic. The scoriæ often contain metallic grains; they are broken and picked with care. All the portions which include some metallic particles are re-melted in an accessory process. The rejected scoriæ have been found to be composed of silicious matter 59, oxyde of copper 1, oxyde of tin 0·7.

In this operation, the copper is concentrated by the separation of a great part of the matters with which it was mixed or combined. The granulated matt produced, contains in general 33 per cent. of copper; it is therefore four times richer than the ore; and its mass is consequently diminished in that proportion. The constituent parts are principally copper, iron, and sulphur.

The most important point to hit in the fusion just described, is to make a fusible mixture of the earths and the oxydes, so that the matt of copper may, in virtue of its greater specific gravity, fall to the under-part, and separate exactly from the slag. This point is attained by means of the metallic oxydes contained in the scoriæ of the fourth operation, of which 2 cwt. were added to the charge. These consist almost entirely of black oxyde of iron. When the ores are very difficult to melt, a measure of about half a hundred-weight of fluor spar is added; but this must be done with precaution, for fear of increasing the scoriæ too much.

The business goes on day and night. Five charges are commonly put through hands in the course of 24 hours; but when all circumstances are favorable—that is to say, when the ore is fusible, when the fuel is of the first quality, and when the furnace is in good condition, even six charges a day have been despatched.

The charge is a ton and a half of calcined ore, so that a melting furnace corresponds nearly to a calcining furnace; the latter turning out nearly 7 tons of calcined ore in 24 hours.

The workmen are paid by the ton.

Third operation. Calcination of the coarse metal, or the matt.—The object of this operation is principally to oxydize the iron, an oxydation easier to execute than in the first calcining, because the metal is now disengaged from the earthy substances, which screened it from the action of the air.

This calcination is executed in the furnace already represented, *figs.* 368, 369, 370, page 470, exactly in the same way as the ore was calcined. The metal must be perpetually stirred about, to expose all its surfaces to the action of the hot air, and to hinder the clotting together. The operation lasts 24 hours; during the first six, the fire should be very moderate, and thereafter gradually increased to the end of the calcination. The charge is, like that of the first, 3 tons and a half.

Fourth operation. Melting of the calcined coarse metal, or calcined matt.—In the fusion of this first calcined matt, some scoriæ of the latter operations must be added, which are very rich in oxyde of copper, and some crusts from the hearth, which are likewise impregnated with it. The proportion of these substances varies according to the quality of the calcined matt.

In this second fusion, the oxyde of copper contained in the scoriæ is reduced by the affinity of the sulphur, one portion of which passes to the state of acid, while the other forms a subsulphuret with the copper become free. The matt commonly contains a sufficient quantity of sulphur to reduce the oxyde of copper completely; but if not, which may happen if the calcination of the matt has been pushed too far, a small quantity of uncalcined matt must be introduced, which, by furnishing sulphur, diminishes the richness of the scoriæ, and facilitates the fusion.

The scoriæ are taken out by the front door, by drawing them forward with a rake. They have a great specific gravity; are brilliant with metallic lustre, very crystalline, and present, in the cavities, crystals like those of pyroxene; they break easily into very sharp-edged fragments. They contain no granulated metal in the interior; but it sometimes occurs, on account of the small thicknesses of the stratum of scoriæ, that these carry off with them, when they are withdrawn, some metallic particles.

These scoriæ, as we have already stated, under the fusion of the roasted ore, are in general melted with it. In some cases, however, a special melting is assigned to them.

The matt obtained in this second fusion is either run out into water like the first, or moulded into pigs (ingots), according to the mode of treatment which it is to undergo. This matt, called by the smelters *fine metal* when it is granulated, and *blue metal* when it is in pigs, is of a light gray color, compact, and bluish at the surface. It is collected in the first form when it is to be calcined anew; and in the second, when it must immediately undergo the operation of *roasting*. Its contents in copper are 60 *per cent.* This operation, which is sometimes had recourse to, lasts 5 or 6 hours. The charge is 1 ton.

(*b*) *Particular fusion of the scoriæ of the fourth operation.*—In re-melting these scoriæ, the object is to procure the copper which they contain. To effect this fusion, the scoriæ are mixed with pulverized coal. or other carbonaceous matters. The copper and several other metals are deoxydized, and furnish a white and brittle alloy. The scoriæ resulting from this melting are in part employed in the first melting, and in part thrown away. They are crystalline, and present crystals often in the cavities, which appear to belong to bisilicate of iron. They have a metallic lustre, and break into very sharp-edged fragments. The white metal is melted again, and then united to the product of the second fusion.

Fifth operation. Calcination of the second matt, or fine metal of the smelter.—This is executed in precisely the same way as that of the first matt. It lasts 24 hours; and the charge is usually 3 tons.

Sixth operation. Melting of the calcined fine metal.—This fusion is conducted like that of the first matt. The black copper, or coarse copper, which it produces, contains from 70 to 80 per cent. of pure metal; it is run into ingots, in order to undergo the operation of roasting.

The scoriæ are rich in copper; they are added to the fusion of the calcined coarse metal of the fourth operation.

In the smelting houses of Messrs. Vivian, at Hafod, near Swansea, the fifth and sixth operations have been omitted of late years. The second matt is run into pigs, under the name of *blue metal*, to be immediately exposed to the roasting.

The disposition of the canal *a a′*, *fig.* 374, which introduces a continuous current of air to the hearth of the furnace, accelerates and facilitates the calcination of the matt; an advantage which has simplified the treatment, by diminishing the number of calculations.

Seventh operation. Roasting of the coarse copper, the product of the sixth operation.—The chief object of this operation is oxydizement: it is performed either in an ordinary roasting furnace, or in the one belonging to *fig.* 374, which admits a constant current of air. The pigs of metal derived from the preceding melting are exposed, on the hearth of the furnace, to the action of the air, which oxydizes the iron and other foreign metals with which the copper is still contaminated. The duration of the roasting varies from

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12 to 24 hours, according to the degree of purity of the crude copper. The temperature should be graduated, in order that the oxydizement may have time to complete, and that the volatile substances which the copper still retains may escape in the gaseous form. The fusion must take place only towards the end of the operation.

The charge varies from a ton and a quarter to a ton and a half. The metal obtained is run out into moulds of sand. It is covered with black blisters, like steel of cementation; whence it has got the name of blistered copper. In the interior of these pigs, the copper presents a porous texture, occasioned by the ebullition produced by the escape of the gases during the moulding. The copper being now almost entirely purged from the sulphur, iron, and the other substances with which it was combined, is in a fit state to be refined. This operation affords some scoriæ; they are very heavy, and contain a great deal of oxyde of copper, sometimes even metallic copper.

These scoriæ, as well as those of the third melting and of the refining, are added to the second fusion, as we have already stated, in describing the fourth operation.

In some works, the roasting is repeated several times upon the *blue metal*, in order to bring it to a state fit for refining. We shall afterwards notice this modification of the treatment.

Eighth operation. Refining or toughening.—The pigs of copper intended for refining are put upon the sole of the refining furnace through the door in the side. A slight heat is first given, to finish the roasting or oxydation, in case this operation has not already been pushed far enough. The fire is to be increased by slow degrees, so that, by the end of 6 hours, the copper may begin to flow. When all the metal is melted, and when the heat is considerable, the workman lifts up the door in the front, and withdraws with a rake the few scoriæ which may cover the copper bath. They are red, lamellated, very heavy, and closely resemble protoxyde of copper.

The refiner takes then an assay with a small ladle, and when it cools, breaks it in a vice, to see the state of the copper. From the appearance of the assay, the aspect of the bath, the state of the fire, &c., he judges if he may proceed to the toughening, and what quantity of wooden spars and wood charcoal he must add to render the metal malleable, or, in the language of the smelters, bring it to the proper pitch. When the operation of refining begins, the copper is brittle or dry, and of a deep red color approaching to purple. Its grain is coarse, open, and somewhat crystalline.

To execute the refining, the surface of the metal is covered over with wood charcoal, and stirred about with a spar or rod of birch wood. The gases which escape from the wood occasion a brisk effervescence. More wood charcoal is added from time to time. so that the surface of the metal may be always covered with it, and the stirring is continued with the rods, till the operation of refining be finished, a circumstance indicated by the assays taken in succession. The grain of the copper becomes finer and finer, and its color gradually brightens. When the grain is extremely fine, or *closed*, when the trial pieces, half cut through and then broken, present a silky fracture, and when the copper is of a fine light red, the refiner considers the operation to be completed; but he verifies still further the purity of the copper, by trying its malleability. For this purpose, he takes out a sample in his small ladle, and pours it into a mould. When the copper is solidified, but still red-hot, he forges it. If it is soft under the hammer, if it does not crack on the edges, the refiner is satisfied with its ductility, and he pronounces it to be in its *proper state*. He orders the workmen to mould it; who then lift the copper out of the furnace in large iron ladles lined with clay, and pour it into moulds of the size suitable to the demands of commerce. The ordinary dimensions of the ingots or pigs are 12 inches broad, 18 long, and from 2 to 2½ thick.

The period of the refining process is 20 hours. In the first six, the metal heats, and suffers a kind of roasting; at the end of this time it melts. It takes four hours to reach the point at which the refining, properly speaking, begins; and this last part of the process lasts about 4 hours. Finally, 6 hours are required to arrange the moulds, cast the ingots, and let the furnace cool.

The charge of copper in the refining process depends upon the dimensions of the furnace. In the Hafod works, one of the most important in England, the charge varies from 3 to 5 tons; and the quantity of pure copper manufactured in a week is from 40 to 50 tons.

The consumption of fuel is from 15 to 18 parts of coal, for one part of refined copper in pigs.

When the copper offers difficulties in the refining, a few pounds of lead are added to it. This metal, by the facility with which it scorifies, acts as a purifier, aiding the oxydation of the iron and other metals that may be present in the copper. The lead ought to be added immediately after removing the door to skim the surface. The copper should be constantly stirred up, to expose the greatest possible surface to the action of the air, and to produce the complete oxydation of the lead; for the smallest quantity of this metal alloyed in copper, is difficult to clear up in the lamination; that is to say, the scale of oxyde does not come cleanly from the surface of the sheets.

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The operation of refining copper is delicate, and requires, upon the part of the workmen, great skill and attention to give the metal its due ductility. Its surface ought to be entirely covered with wood charcoal; without this precaution, the refining of the metal would *go back*, as the workmen say, during the long interval which elapses in the moulding; whenever this accident happens, the metal must be stirred up anew with the wooden pole.

Too long employment of the wooden rod gives birth to another remarkable accident for the copper becomes more brittle than it was prior to the commencement of the refining; that is, when it was *dry*. Its color is now of a very brilliant yellowish red, and its fracture is fibrous. When this circumstance occurs, when the refining, as the workmen say, has *gone too far*, the refiner removes the charcoal from the top of the melted metal; he opens the side door, to expose the copper to the action of the air, and it then resumes its malleable condition.

Mr. Vivian, to whom we owe the above very graphic account of the processes, has explained, in a very happy manner, the theory of refining. He conceives, we may conclude, that the copper in the *dry state*, before the refining, is combined with a small portion of oxygen, or, in other words, that a small portion of oxyde of copper is diffused through the mass, or combined with it; and that this proportion of oxygen is expelled by the deoxydizing action of the wood and charcoal, whereby the metal becomes malleable. 2. That when the refining process is carried too far, the copper gets combined with a little charcoal. Thus copper, like iron, is brittle when combined with oxygen and charcoal; and becomes malleable only when freed entirely from these two substances.

It is remarkable, that copper, in the *dry state*, has a very strong action upon iron; and that the tools employed in stirring the liquid metal become very glistening, like those used in a farrier's forge. The iron of the tools consumes more rapidly at that time, than when the copper has acquired its malleable state. The metal requires, also, when *dry*, more time to become solid, or to cool, than when it is refined; a circumstance depending, probably, upon the difference in fusibility of the copper in the two states, and which seems to indicate, as in the case of iron, the presence of oxygen.

When the proper refining point has been passed, another very remarkable circumstance has been observed; namely, that the surface of the copper oxydizes more difficultly, and that it is uncommonly brilliant; reflecting clearly the bricks of the furnace vault. This fact is favorable to the idea suggested above, that the metal is in that case combined with a small quantity of carbon; which absorbs the oxygen of the air, and thus protects the metal from its action.

Copper is brought into the market in different forms, according to the purposes which it is to serve. What is to be employed in the manufacture of brass is granulated. In this condition it presents more surface to the action of zinc or calamine, and combines with it more readily. To produce this granulation, the metal is poured into a large ladle pierced with holes, and placed above a cistern filled with water, which must be hot or cold, according to the form wished in the grains. When it is hot, round grains are obtained analogous to lead shot; and the copper in this state is called *bean shot*. When the melted copper falls into cold water perpetually renewed, the granulations are irregular, thin, and ramified; constituting *feathered shot*. The *bean shot* is the form employed in brass making.

Copper is also made into small ingots, about 6 ounces in weight. These are intended for exportation to the East Indies, and are known in commerce by the name of Japan copper. Whenever these little pieces are solidified, they are thrown, while hot, into cold water. This immersion slightly oxydizes the surface of the copper, and gives it a fine red color.

Lastly, the copper is often reduced into sheets, for the sheathing of ships, and many other purposes. The Hafod works possess a powerful rolling mill, composed of four pairs of cylinders. It is moved by a steam engine, whose cylinder has 40 inches diameter. See the representation of the rolling mill of the Royal Mint, under GOLD.

The cylinders for rolling copper into sheets are usually 3 feet long, and 15 inches in diameter. They are uniform. The upper roller may be approached to the under one, by a screw, so that the cylinders are brought closer, as the sheet is to be made thinner.

The ingots of copper are laid upon the sole of a reverberatory furnace to be heated; they are placed alongside each other, and they are formed into piles in a cross-like arrangement, so that the hot air may pass freely round them all. The door of the furnace is shut, and the workman looks in through a peep-hole from time to time, to see if they have taken the requisite temperature; namely, a dull red. The copper is now passed between the cylinders; but although this metal be very malleable, the ingots cannot be reduced to sheets without being several times heated; because the copper cools, and acquires, by compression, a texture which stops the progress of the lamination.

These successive heatings are given in the furnace indicated above; though, when the sheets are to have a very great size, furnaces somewhat different are had recourse to. They are from 12 to 15 feet long, and 5 wide. See Brass.

The copper, by successive heating and lamination, gets covered with a coat of oxyde, which is removed by steeping the sheets for a few days in a pit filled with urine; they are then put upon the sole of the heating furnace. Ammonia is formed, which acts on the copper oxyde, and lays bare the metallic surface. The sheets are next rubbed with a piece of wood, then plunged, while still hot, into water, to make the oxyde scale off; and lastly, they are passed cold through the rolling press to smooth them. They are now cut square, and packed up for home sale or exportation.

The following estimate has been given by MM. Dufrenoy and Elie de Beaumont of the expense of manufacturing a ton of copper in South Wales.

	£	s.	d.
12½ tons of ore, yielding 8½ *per cent.* of copper	55	0	0
20 tons of coals - - - - -	8	0	0
Workmen's wages, rent, repairs, &c. - -	13	0	0
	76	0	0

The exhalations from the copper smelting works are very detrimental to both vegetable and animal life. They consist of sulphurous acid, sulphuric acid, arsenic, and arsenious acids, various gases and fluoric vapors, with solid particles mechanically swept away into the air, besides the coal smoke. Mr. Vivian has invented a very ingenious method of passing the exhalations from the calcining ores and *matts* along horizontal flues, or rather galleries of great dimensions, with many crossings and windings of the current, and exposure during the greater part of the circuit to copious showers of cold water. By this simple and powerful system of condensation, the arsenic is deposited in the bottoms of the flues, the sulphurous acid is in a great measure absorbed, and the nuisance is remarkably abated.

The following figures represent certain modifications of the copper calcining and smelting copper furnaces of Swansea.

Fig. 376, is the section of the roasting furnace lengthwise; *fig.* 375, the ground plan; in which *a* is the fire-door; *b* the grate; *c* the fore-bridge; *d* the chimney; *e e* working apertures on each of the long sides of the furnace, through which the ore is introduced, spread, and turned over; *f f* cast-iron hoppers; *g g* openings in the vaulted roof; *h* the hearth-sole; *i i* holes in this; *k* a vaulted space under the hearth. The hearth has a suitable oval shape, and is covered with a flat arch. Its length is 16 feet, breadth 13½, mean height 2 feet.

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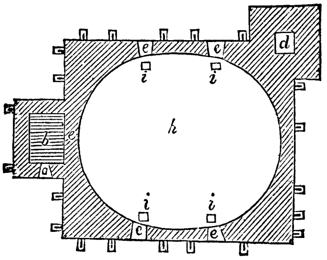

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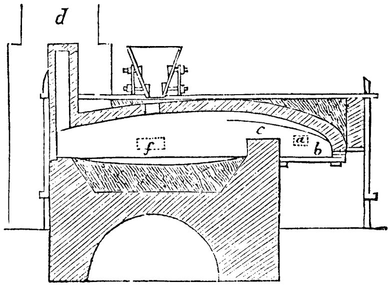

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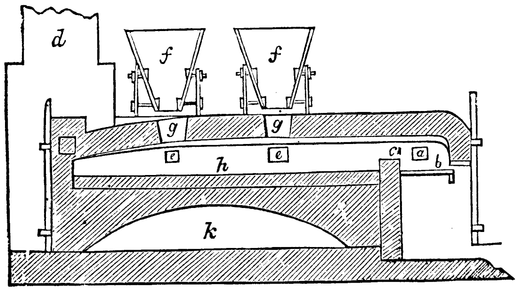
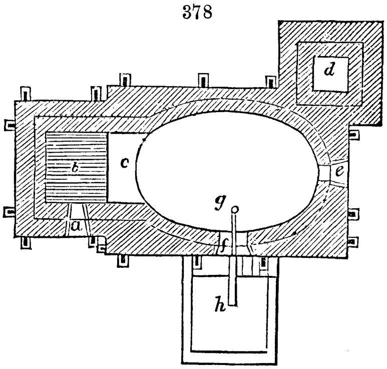


Fig. 377, is a longitudinal section of the melting furnace; *fig.* 378, the ground plan, in which *a* is the fire door; *b* the grate; *c* the fire bridge; *d* the chimney; *e* the side openings; *f* the working doors; *g* the raking-out hole; *h* iron spouts, which conduct the melted metal into pits filled with water.

The melting furnace is altogether smaller; but its firing hearth is considerably larger than in the roasting furnace. The long axis of the oval hearth is 14 feet; its short axis 10 feet; its mean height 2 feet.

378



The principal ore smelted at Chessy is the azure copper, which was discovered by accident in 1812. Red copper ore, also, has come into operation there since 1825. The average metallic contents of the richest azure ore are from 33 to 36 per cent.; of the poorer, from 20 to 24. The red ore contains from 40 to 67 parts in 100. The ore is sorted, so that the mean contents of metal may be 27 per cent., to which 20 per cent. of limestone are added; whence the cinder will amount to 50 per cent. of the ore. A few per cents. of red copper slag, with some quicklime and *gahrslag*, are added to each charge, which consists of 200 pounds of the above mixture, and 150 pounds of coke. When the furnace (*fourneau à manche*, see the Scotch smelting hearth, under Lead) is in good action, from 10 to 14 such charges are worked in 12 hours. When the crucible is full of metal at the end of this period, during which the cinder has been frequently raked off, the blast is stopped, and the *matte* floating over the metal being sprinkled with water and taken off, leaves the black copper to be treated in a similar way, and converted into *rosettes.* The refining of this black copper is performed in a kind of reverberatory furnace.

The cinders produced in this reduction process are either vitreous and light blue, which are most abundant; cellular, black, imperfectly fused from excess of lime; or, lastly, red, dense, blistery, from defect of lime, from too much heat, and the passage of protoxyde into the cinders. They consist of silicate of alumina, of lime, protoxyde of iron; the red contain some silicate of copper.

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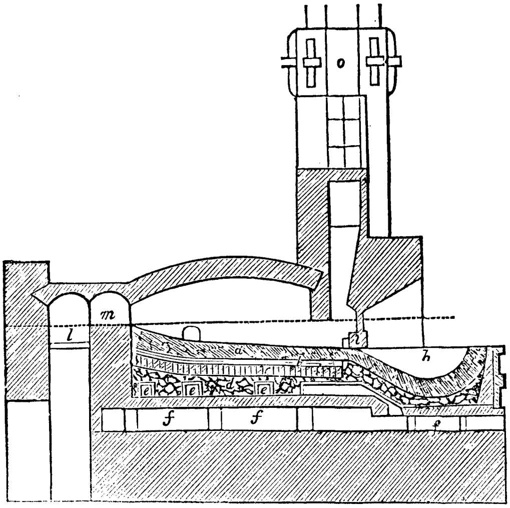

The copper-refining furnace at Chessy, near Lyons, is of the kind called *Spleiss-ofen* (split hearths) by the Germans. *Fig.* 379 is a section lengthwise in the dotted line A B of *fig.* 380, which is the ground plan.

The foundation-walls are made of gneiss; the arch, the fire-bridge, and the chimney, of fire-bricks. The hearth, *a*, is formed of a dense mixture of coal-dust, upon a bottom of well-beat clay, *b*, which reposes upon a bed of brickwork *c*. Beneath this there is a slag bottom *d; e* is the upper, and *f* the under discharge hole. The hearth is egg-shaped; the longer axis being 8 feet, the shorter 6½ feet; in the middle it is 10 inches deep, and furnished with the outlets *g g*, which lead to each of the *Spleiss-hearths h h*, *fig.* 380. These outlets are contracted with fire-bricks *i i*, till the proper period of the discharge. The two hearths are placed in communication by a canal *k:* they are 3½ feet in diameter, 16 inches deep; are floored with well-beat coal ashes, and receive about 27 cwt. for a charge.

l is the grate; *m*, the fire-bridge; *n*, the boshes in which the *tuyères* lie; *o*, the chimney; *p*, the working door through which the slags may be drawn off. Above this is a small chimney, to carry off the flame and smoke whenever the door is opened.

The smelting *post* or charge, to be purified at once, consists of 60 cwt. of black copper, to which a little granular copper and copper of cementation is added; the consumption of pit-coal amounts to 36 cwt. As soon as the copper is melted, the bellows are set a-going, and the surface of the metal gets soon covered with a

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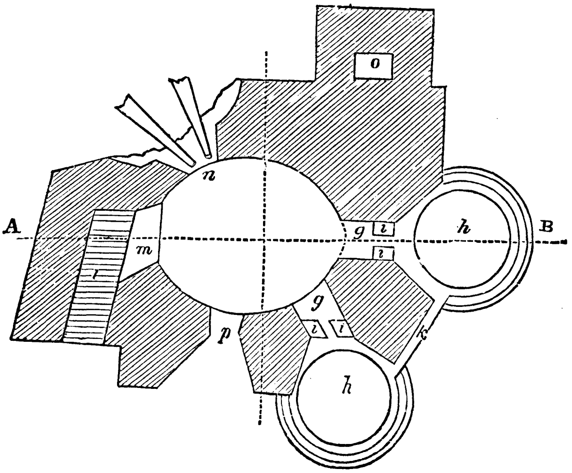

moderately thick layer of cinder, which is drawn off. This is the first skimming or *decrassage*. By and by, a second layer of cinder forms, which is in like manner removed; and this skimming is repeated, to allow the blast to act upon fresh metallic surfaces. After 4 or 5 hours, no more slag appears, and then the fire is increased. The melted mass now begins to boil or work (*travailler*), and continues so to do, for about ¾ of an hour, or an hour, after which the motion ceases, though the fire be kept up. The *gahrproof* is now taken; but the metal is seldom fine in less than ¾ of an hour after the boil is over. Whenever the metal is run off by the tap-hole into the two basins *i i*, called SPLIT-HEARTHS, a reddish vapor or mist rises from its surface, composed of an infinite number of minute globules, which revolve with astonishing velocity upon their axes, constituting what the Germans called *spratzen* (crackling) of the copper. They are composed of a nucleus of metal, covered with a film of protoxyde, and are used as sand for strewing upon manuscript. The copper is separated, as usual, by sprinkling water upon the surface of the melted metal, in the state of *rosettes*, which are immediately immersed in a stream of water. This refining process lasts about 16 or 17 hours; the skimmings weigh about 50 cwt.; the refuse is from 15 to 17 per cent.; the loss from 2 to 3 per cent. The *gahrslag* amounts to 11 cwt.

The refining of the eliquated copper (called *darrlinge*) from which the silver has been sweated out by the intervention of lead, can be performed only in small hearths. The following is the representation of such a furnace, called, in German, *Kupfergahrheerd*. *Fig.* 381 is the section lengthwise; *fig.* 382 is the section across; and *fig.* 383 is the

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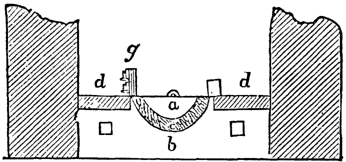

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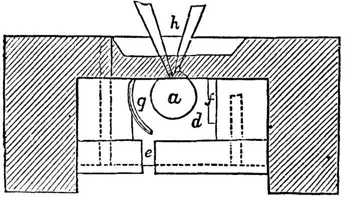

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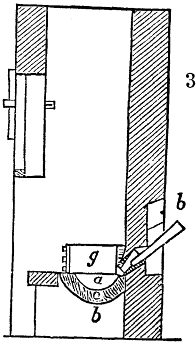


ground plan, in which *a* is the hearth-hollow; *b*, a massive wall; *c*, the mass out of which the hearth is formed; *d*, cast-iron plates covering the hearth; *e*, opening for running off the liquid slag; *f*, a small wall; g, iron curb for keeping the coals together.

The hearth being heated with a bed of charcoal, ¾ cwt. of *darrlinge* are laid over it, and covered with more fuel: whenever this charge is melted, another layer of the coal and *darrlinge* is introduced, and thus in succession till the hearth become full, or contain from 2¼ to 2½ cwt. In Neustadt 7½ cwt. of *darrlinge* have been refined in one furnace, from which 5 cwt. of *gahrcopper* has been obtained. The blast oxydizes the foreign metals, namely, the lead, nickel, cobalt, and iron, with a little copper, forming the *gahrslag;* which is, at first, rich in lead oxyde, and poor in copper oxyde; but, at the end, this order is reversed The slag, at first blackish, assumes progressively a copper red tint. The slag flows off spontaneously along the channel *e*, from the surface of the hearth. The *gahre* is tested by means of a proof-rod of iron, called *gahr-eisen*, thrust though the *tuyère* into the melted copper, then drawn out and plunged in cold water. As soon as the *gahrspan* (scale of copper) appears brownish red on the outside, and copper red within, so thin that it seems like a net-work, and so deficient in tenacity that it cannot be bent without breaking, the refining is finished. The blast is then stopped; the coals covering the surface, as also the cinders, must be raked off the copper, after being left to cool a little; the surface is now cooled by sprinkling water upon it, and the thick cake of congealed metal (*rondelle*) is lifted off with tongs, a process called *schleissen* (slicing), or *sheibenreissen* (shaving), which is continued till the last convex cake at the bottom of the furnace, styled the *kingspiece*, is withdrawn. These *rondelles* are immediately immersed in cold water, to prevent the oxydation of the copper; whereupon the metal becomes of a cochineal red color, and gets covered with a thin film of protoxyde. Its under surface is studded over with points and hooks, the result of tearing the congealed disc from the liquid metal. Such cakes are called *rosette* copper. When the metal is very pure and free from protoxyde, these cakes may be obtained very thin, one 24th of an inch for example.

The refining of two cwts. and a half of *darrlinge* takes three quarters of an hour, and yields one cwt. and a half of *gahrcopper* in 36 rosettes, as also some *gahrslag*. Gahrcopper generally contains from 1½ to 2½ per cent. of lead, along with a little nickel, silver, iron, and aluminum.

Smelting of the Mannsfeld copper schist, or bituminous Mergelschiefer.—The cupreous ore is first roasted in large heaps, of 2000 cwts., interstratified with brush-wood, and with some slates rich in bituminous matter, mixed with the others. These heaps are 3 ells high, and go on burning 15 weeks in fair and 20 in rainy weather. The bitumen is decomposed; the sulphur is dissipated chiefly in the form of sulphurous acid; the metal gets partially oxydized, particularly the iron, which is a very desirable circumstance towards the production of a good smelting slag. The calcined ore is diminished one tenth in bulk, and one eighth in weight; becoming of a friable texture and a dirty yellow gray color. The smelting furnaces are cupolas (*schachtofen*), 14 to 18 feet high; the fuel is partly word charcoal, partly coke from the Berlin gas-works, and Silesia. The blast is given by cylinder bellows, recently substituted for the old barbarous *Blasebälgen*, or wooden bellows of the household form.

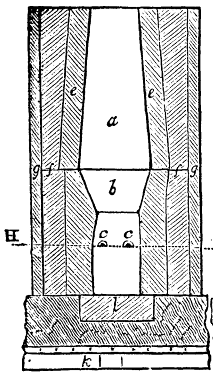
The cupreous slate is sorted, according to its composition, into slate of lime, clay, iron, &c., by a mixture of which the smelting is facilitated. For example, 1 post or charge may consist of 20 cwt. of the ferruginous slate, 14 of the calcareous, 6 of the argillaceous, with 3 of fluor spar, 3 of rich copper slags, and other refuse matters. The nozzle at the *tuyère* is lengthened 6 or 8 inches, to place the melting heat near the centre of the furnace. In 15 hours 1 fodder of 48 cwts. of the above mixture may be smelted, whereby 4 to 5 cwts. of *matte* (crude copper, called *Kupferstein* in Germany) and a large body of slags are obtained. The *matte* contains from 30 to 40 per cent. of copper, and from 2 to 4 *loths* (1 to 2 oz.) of silver. The slags contain at times one tenth their weight of copper.

The *matte* is composed of the sulphurets of copper, iron, silver, zinc, along with some arsenical cobalt and nickel. The slaty slag is raked off the surface of the melted *matte* from time to time. The former is either after being roasted six successive times, smelted into black copper; or it is subjected to the following concentration process. It is broken to pieces, roasted by brushwood and coals three several times in brick-walled kilns, containing 60 cwts., and turned over after every calcination; a process of four weeks' duration. The thrice roasted mass, called *spurrost*, being melted in the cupola *fig.* 385, with ore-cinder, yields the *spurstein*, or concentrated *matte*. From 30 to 40 cwts. of spurrost are smelted in 24 hours; and from 48 to 60 per cent. of *spurstein* are obtained, the slag from the slate smelting being employed as a flux. The spurstein contains from 50 to 60 per cent. of copper, combined with the sulphurets of copper, of iron, and silver.

The spurstein is now mixed with *dünnstein* (a sulphuret of copper and iron produced in the original smeltings) roasted six successive times, in the quantity of 60 cwts., with brushwood and charcoal; a process which requires from 7 to 8 weeks. The product of this six-fold calcination is the *Gahrrost* of the Germans (done and purified); it has a color like red copper ore, varying from blue gray into cochineal red; a granular fracture; it contains a little of the metal, and may be immediately reduced into metallic copper, called *kupfermachen.* But before smelting the mass, it is lixiviated with water, to extract from it the soluble sulphate, which is concentrated in lead pans, and crystallized.

The lixiviated *gahröste* mixed with from $\frac{1}{4}$ to $\frac{1}{5}$ of the lixiviated *dünnsteinrost,* and $\frac{1}{6}$ to $\frac{1}{13}$ of the copper slate slag, are smelted with charcoal or coke fuel in the course of 24 hours, in a mass of 60 or 80 cwts. The product is black copper, to the amount of about $\frac{1}{4}$ the weight, and $\frac{1}{6}$ of *dünnstein* or *thin matte.* This black copper contains in the cwt. from 12 to 20 loths (6 to 10 oz.) of silver. The dünnstein consists of from 60 to 70 per cent. of copper combined with sulphur, sulphuret of iron, and arsenic: and when thrice roasted, yields a portion of metal. The black copper lies undermost in the crucible of the furnace; above it is the *dünnstein,* covered with the stone slag, or copper cinder, resulting from the slate-smelting. The slags being raked off, and the crucible sufficiently full, the eye or nozzle hole is shut, the *dünnstein* removed by cooling the surface and breaking the crust, which is about $\frac{1}{4}$ to $\frac{1}{2}$ inch thick. The same method is adopted for taking out the black copper in successive layers. For the de-silvering of this and similar black coppers, see SILVER.

385



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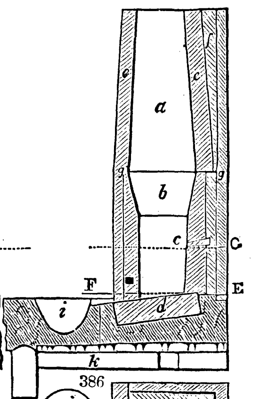

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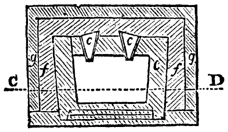

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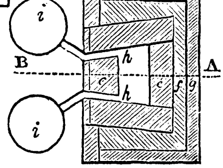

Fig. 384 is a vertical section through the form or *tuyère* in the dotted line A B of *fig.* 386. *Fig.* 385 is a vertical section in the dotted line C D of *fig.* 387. *a* is the shaft of the furnace, *b* the rest, *c c* the forms; *d* the sole or hearth-stone, which has a slope of 3 inches towards the front wall; *e e,* &c. casing walls of fire bricks; *f f,* &c. filling up walls built of rubbish stones; *g g* a mass through which the heat is slowly conducted; *h h* the two holes through one or other of which alternately the product of the smelting process is run off into the fore-hearth. Beneath the hearth-sole there is a solid body of loam; and the fore-hearth is formed with a mixture of coal-dust and clay; *k* is the discharge outlet. *Fig.* 386 is a horizontal section of the furnace through the hole or eye in the dotted line E F of *fig.* 384; *fig.* 387, a horizontal section of the shaft of the furnace through the form in the dotted line G H of *figs.* 384 and 385. The height of the shaft, from the line E F to the top, is 14 feet; from E to G, 25 inches; from *c* to the line below *b,* 2 feet; from that line to the line opposite g g, 2 feet. The width at the line *g g* is 3 feet 3 inches, and at *c* 26 inches. The basins *i i, fig.* 386, are 3 feet diameter, and 20 inches deep.

The refining of copper is said to be well executed at Seville, in Spain; and, therefore, some account of the mode of operating there may be acceptable to the reader.

The first object is to evaporate in a reverberatory furnace all the volatile substances, such as sulphur, arsenic, antimony, &c., which may be associated with the sulphur; and the second, to oxydize and to convert into scoriæ the fixed substances, such as iron, lead, &c., with the least possible expense and waste. The minute quantities of gold and silver which resist oxydation cannot be in any way injurious to the copper. The hearth is usually made of a refractory sand and clay with ground charcoal, each mixed in equal volumes, and worked up into a doughy consistence with water. This composition is beat firmly into the furnace bottom. But a quartzose hearth is found to answer better, and to be far more durable; such as a bed of fire-sandstone.

Before kindling the furnace, its inner surface is smeared over with a cream-consistenced mixture of fire-clay and water.

The cast pigs, or blocks of black or crude copper, are piled upon the hearth, each successive layer crossing at right angles the layer beneath it, in order that the flame may

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have access to play upon the surface of the hearth, and to heat it to a proper pitch for making the metal flow.

The weight of the charge should be proportional to the capacity of the furnace, and such that the level of the metallic bath may be about an inch above the nozzle of the bellows; for, were it higher, it would obstruct its operation, and were it too low, the stream of air would strike but imperfectly the surface of the metal, and would fail to effect, or would retard at least, the refining process, by leaving the oxydation and volatilization of the foreign metals incomplete.

As the scoriæ form upon the surface, they are drawn off with an iron rabble fixed to the end of a wooden rod.

Soon after the copper is melted, charcoal is to be kindled in three iron basins lined with loam, placed alongside the furnace, to prepare them for receiving their charge of copper, which is to be converted in them, into *rosettes.*

The bellows are not long in action before the evaporation of the mineral substances is so copious, as to give the bath a boiling appearance; some drops rise up to the roof of the reverberatory, others escape by the door, and fall in a shower of minute spherical globules. This phenomenon proves that the process is going on well; and, when it ceases, the operation is nearly completed. A small proof of copper, of the form of a watch-case, and therefore called *montre*, is taken out from time to time, upon the round end of a polished iron rod, previously heated. This rod is dipped two or three inches into the bath, then withdrawn and immersed in cold water. The copper cap is detached from the iron rod, by a few blows of a hammer; and a judgment is formed from its thickness, color, and polish, as to the degree of purity which the copper has acquired. But these *watches* need not be drawn till the small rain, above spoken of, has ceased to fall At the end of about 11 hours of firing, the numerous small holes observable in the first *watch* samples begin to disappear; the outer surface passes from a bright red to a darker hue, the inner one becomes of a more uniform color, and always less and less marked with yellowish spots. It will have acquired the greatest pitch of purity that the process can bestow, when the *watches* become of a dark crimson color.

Care must be taken to stop this refining process at the proper time; for, by prolonging it unduly, a small quantity of cupreous oxyde would be formed, which, finding no oxygen to reduce it, would render the whole body of copper hard, brittle, and incapable of lamination.

The basins must now be emptied of their burning charcoal, the opening of the *tuyère* must be closed, and the melted copper allowed to flow into them through the tap-hole, which is then closed with loam. Whenever the surface is covered with a solid crust, it is bedewed with water; and as soon as the crust is about 1½ inch thick it is raised upon hooks above the basin, to drain off any drops, and then carried away from the furnace. If these cakes, or rosettes, be suddenly cooled by plunging them immediately in water, they will assume a fine red color, from the formation of a film of oxyde.

Each refining operation produces, in about 12 hours, $1\frac{7}{10}$ tons of copper, with the consumption of about $\frac{4}{5}$ of a ton of dry wood.

Care should be taken that the copper cake or *rosette* be all solidified before plunging it into water, otherwise a very dangerous explosion might ensue, in consequence of the sudden extrication of oxygen from the liquid metal, in the act of condensation. On the other hand, the cake should not be allowed to cool too long in the air, lest it get peroxydized upon the surface, and lose those fine red, purple, and yellow shades, due to a film of the protoxyde, which many dealers admire.

When a little oxyde of antimony and oxyde of copper are combined with copper, they occasion the appearance of micaceous scales in the fractured faces. Such metal is hard, brittle, yellowish within, and can be neither laminated nor wire-drawn. These defects are not owing to arsenic, as was formerly imagined; but, most probably, to antimony in the lead, which is sometimes used in refining copper. They are more easily prevented than remedied.

According to M. Frèrejean, proprietor of the great copper works of Vienne, in Dauphiny, too low a temperature, or too much charcoal, gives to the metal a cubical structure, or that of divergent rays; in either of which states it wants tenacity. Too high a temperature, or too rapid a supply of oxygen, gives it a brick red color, a radiated crystallization without lustre, or a very fine grain of indeterminate form; the last structure being unsuitable for copper that is to be worked under the hammer or in the rolling-press. The form which indicates most tenacity is radiated with minute fibres glistening in mass. Melted copper will sometimes pass successively through these three states in the space of ten minutes.

Fig. 388 represents a *roasting mound* of copper pyrites in the Lower Hartz, near Goslar, where a portion of the sulphur is collected. It is a vertical section of a truncated quadrangular pyramid. A layer of wooden billets is arranged at the base of the pyramid in the line *a a.*

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c, a wooden chimney which stands in the centre of the mound with a small pile of charcoal at its bottom, c; *d d* are large lumps of ore surrounded by smaller pieces; *f f* are rubbish and earth to form a covering. A current of air is admitted under the billets by an opening in the middle of each of the four sides of the base *a a*, so that two principal currents of air cross under the vertical axis c of the truncated pyramid, as indicated in the figure.

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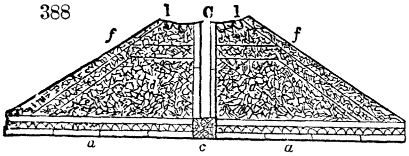

The fire is applied through the chimney c; the charcoal at its bottom *c*, and the piles *a a* are kindled. The sulphureous ores, *d f*, are raised to such a high temperature as to expel the sulphur in the state of vapor.

In the Lower Hartz a roasting mound continues burning during four months. Some days after it is kindled the sulphur begins to exhale, and is condensed by the air at the upper surface of the pyramid. When this seems impregnated with it, small basins 1 1 are excavated, in which some liquid sulphur collects; it is removed from time to time with iron ladles, and thrown into water, where it solidifies. It is then refined and cast into roll brimstone.

A similar roasting mound contains, in the Lower Hartz, from 100 to 1[illegible]0 tons of ore and 730 cubic feet of wood. It yields in four months about one ton and a half of sulphur from copper pyrites. Lead ore is treated in the same way, but it furnishes less sulphur.

There are usually from 12 to 15 roasting heaps in action at once for three smelting works of the Lower Hartz. After the first roasting two heaps are united to form a third, which is calcined anew, but under a shed; the ores are then stirred up and roasted for the third time, whence a crude mixture is procured for the smelting-house.

The most favorable seasons for roasting in the open air are spring and autumn; the best weather is a light wind accompanied with gentle rain. When the wind or rain obstructs the operation, this inconvenience is remedied by planks distributed round the upper surface of the truncated pyramid over the sulphur basins.

Manufacturing assays of copper.—The first thing is to make such a sample as will represent the whole mass to be valued; with which view, fragments must be taken from different spots, mixed, weighed, and ground together. A portion of this mixture being tried by the blow-pipe, will show, by the garlic or sulphurous smell of its fumes, whether arsenic, sulphur, or both, be the mineralizers. In the latter case, which often occurs, 100 gr. or 1000 gr. of the ore are to be mixed with one half its weight of saw-dust, then imbued with oil, and heated moderately in a crucible till all the arsenical fumes be dissipated. The residuum, being cooled and triturated, is to be exposed in a shallow earthen cup to a slow roasting heat, till the sulphur and charcoal be burned away. What remains, being ground and mixed with half its weight of calcined borax, one twelfth its weight of lamp black, next made into a dough with a few drops of oil, is to be pressed down into a crucible, which is to be covered with a luted lid, and to be subjected, in a powerful air furnace, first to a dull red heat, and then to vivid ignition for 20 minutes. On cooling and breaking the crucible, a button of metallic copper will be obtained. Its color and malleability indicate pretty well the quality, as does its weight the relative value of the ore. It should be cupelled with lead, to ascertain if it contains silver or gold. See Assay, and Silver.

If the blow-pipe trial showed no arsenic, the first calcination may be omitted; and if neither sulphur nor arsenic, a portion of the ground ore should be dried, and treated directly with borax, lamp-black, and oil. It is very common to make a dry assay of copper ores, by one roasting and one fusion along with 3 parts of black flux: from the weight of the metallic button the richness of the ore is inferred.

The humid assay is more exact, but it requires more skill and time.

The sulphur and the silica are easily got rid of by the acids, which do not dissolve them, but only the metallic oxydes and the other earths. These oxydes may then be thrown down by their appropriate reagents, the copper being precipitated in the state of either the black oxyde or pure metal. 105 parts of black oxyde represent 100 of copper. Before entering upon the complete analysis of an ore, preliminary trials should be made, to ascertain what are its chief constituents. If it be sulphuret of copper, or copper pyrites, without silver or lead, 100 grains exactly of its average powder may be weighed out, treated in a matrass with boiling muriatic acid for some time, gradually adding a few drops of nitric acid, till all action ceases, or till the ore be all dissolved. The insoluble matter found floating in the liquid contains most of the sulphur; it may be separated upon a filter, washed, dried, and weighed; then verified by burning away. The incombustible residuum, treated by muriatic acid, may leave an insoluble deposite, which is to be added to the former. To the whole of the filtered solutions carbonate of potash is to be added; and the resulting precipitate, being washed, and digested repeatedly in water of ammonia, all its cupric oxyde will have been dissolved, whenever the ammonia is no longer rendered blue.

Caustic potash, boiled with the ammoniacal solution, will separate the copper in the state of black oxyde; which is to be thrown upon a filter, washed. dried, and weighed. The matter left undissolved by the ammonia, consists of oxyde of iron, with probably a little alumina. The latter being separated by caustic potash, the iron oxyde may be also washed, dried, and weighed. The powder which originally resisted the muriatic acid, is silica.

Assay of copper ores, which contain iron, sulphur, silver, lead, and antimony.

100 grains of these ores, previously sampled, and pulverized, are to be boiled with nitric acid, adding fresh portions of it from time to time, till no more of the matter be dissolved. The whole liquors which have been successively digested and decanted off, are to be filtered and treated with common salt, to precipitate the silver in the state of a chloride.

The nitric acid, by its reaction upon the sulphur, having generated sulphuric acid, this will combine with the lead oxydized at the same time, constituting insoluble sulphate of lead, which will remain mixed with the gangue. Should a little nitrate of lead remain in the liquid, it may be thrown down by sulphate of soda, after the silver has been separated. The dilute liquid, being concentrated by evaporation, is to be mixed with ammonia in such excess as to dissolve all the cupric oxyde, while it throws down all the oxyde of iron and alumina; which two may be separated, as usual, by a little caustic potash. The portion of ore insoluble in the nitric acid being digested in muriatic acid, everything will be dissolved except the sulphur and silica. These being collected upon a filter, and dried, the sulphur may be burned away, whereby the proportion of each is determined.

Ores of the oxyde *of copper* are easily analyzed by solution in nitric acid, the addition of ammonia, to separate the other metals, and precipitation by potash. The *native carbonate* is analyzed by calcining 100 grains; when the loss of weight will show the amount of water and carbonic acid; then that of the latter may be found, by expelling it from another 100 grains, by digestion in a given weight of sulphuric acid. The copper is finally obtained in a metallic state by plunging bars of zinc into the solution of the sulphate.

The *native arseniates of copper* are analyzed by drying them first at a moderate heat; after which they are to be dissolved in nitric acid. To this solution, one of nitrate of lead is to be added, as long as it occasions a precipitate; the deposite is to be drained upon a filter, and the clear liquid which passes through, being evaporated nearly to dryness, is to be digested in hot alcohol, which will dissolve everything except a little arseniate of lead. This being added to the arseniate first obtained, from the weight of the whole, the arsenic acid, constituting 35 per cent., is directly inferred. The alcoholic solution being now evaporated to dryness, the residue is to be digested in water of ammonia, when the cupric oxyde will be dissolved, and the oxyde of iron will remain. The copper is procured, in the state of black oxyde, by boiling the filtered ammoniacal solution with the proper quantity of potash.

The analysis of muriate of copper—atacamite—is an easy process. The ore being dissolved in nitric acid, a solution of nitrate silver is added, and from the weight of the chloride precipitated, the equivalent amount of muriate or chloride of copper is given; for 100 of chloride of silver represent 93 of chloride of copper, and 43·8 of its metallic basis. This calculation may be verified by precipitating the copper of the muriate from its solution in dilute sulphuric acid, by plates of zinc.

The phosphate of copper may be analyzed either by solution in nitric acid, and precipitation by potash; or by precipitating the phosphoric acid present, by means of acetate of lead. The phosphate of lead thus obtained, after being washed, is to be decomposed by dilute sulphuric acid. The insoluble sulphate of lead, being washed, dried, and weighed, indicates by its equivalent the proportion of phosphate of lead, as also of phosphate of copper; for 100 of sulphate of lead correspond to 92·25 phosphate of lead, and 89·5 phosphate of copper; and this again to 52·7 of the black oxyde.

Copper forms the basis of a greater number of important ALLOYS than any other metal With zinc, it forms Brass in all its varieties; which see.

BRONZE and BELL METAL are alloys of copper and tin. This compound is prepared in crucibles when only small quantities are required; but in reverberatory hearths, when statues, bells, or cannons are to be cast. The metals must be protected as much as possible during their combination from contact of air by a layer of pounded charcoal, otherwise two evils would result, waste of the copper by combustion, and a rapid oxydizement of the tin, so as to change the proportions and alter the properties of the alloy. The fused materials ought to be well mixed by stirring, to give uniformity to the compound. See BRONZE.

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An alloy of 100 of copper and 4·17 of tin has been proposed by M. Chaudet for the ready manufacture of *medals*. After melting this alloy, he casts it in moulds made of such bone-ash as is used for cupels. The medals are afterward subjected to the action of the coining press, not for striking them, for the mould furnishes perfect impressions, but for finishing and polishing them.

By a recent analysis of M. Berthier, the bells of the *pendules*, or ornamental clocks, made in Paris, are found to be composed—of copper 72·00, tin 26·56, iron 1·44, in 100 parts.

An alloy of 100 of copper and 14 of tin is said by M. Dussaussy to furnish tools, which, hardened and sharpened in the manner of the ancients, afford an edge nearly equal to that of steel.

Cymbals, gongs, and the *tamtam* of the Chinese are made of an alloy of 100 of copper with about 25 of tin. To give this compound the sonorous property in the highest degree, it must be subjected to sudden refrigeration. M. D'Arcet, to whom this discovery is due, recommends to ignite the piece after it is cast, and to plunge it immediately into cold water. The sudden cooling gives the particles of the alloy such a disposition, that, with a regulated pressure by skilful hammering, they may be made to slide over each other, and remain permanently in their new position. When by this means the instrument has received its intended form, it is to be heated and allowed to cool slowly in the air. The particles now take a different arrangement from what they would have done by sudden refrigeration; for instead of being ductile, they possess such an elasticity, that on being displaced by a slight compression, they return to their primary position after a series of extremely rapid vibrations; whence a very powerful sound is emitted. Bronze, bell-metal, and probably all the other alloys of tin with copper, present the same peculiarities.

The alloy of 100 of copper with from 60 to 33 of tin forms common *bell-metal*. It is yellowish or whitish gray, brittle, and sonorous, but not so much so as the preceding. The metal of house-clock bells contains a little more tin than that of church-bells, and the bell of a repeater contains a little zinc in addition to the other ingredients.

The bronze-founder should study to obtain a rapid fusion, in order to avoid the causes of waste indicated above. Reverberatory furnaces have been long adopted for this operation; and among these, the elliptical are the best. The furnaces with spheroidal domes are used by the bell-founders, because their alloy being more fusible, a more moderate melting heat is required; however, as the rapidity of the process is always a matter of consequence, they also would find advantage in employing the elliptical hearths, (*see the form of the melting furnace, as figured under Smelting of copper ores.*) Coal is now universally preferred for fuel.

The alloy of 100 of copper with 50 of tin, or more exactly of 32 of the former with 14½ of the latter, constitutes *speculum* metal, for making mirrors of reflecting telescopes. This compound is nearly white, very brittle, and susceptible of a fine polish with a brilliant surface. The following compound is much esteemed in France for making specula. Melt 2 parts of pure copper and 1 of grain-tin in separate crucibles, incorporate thoroughly with a wooden spatula, and then run the metal into moulds. The lower surface is the one that should be worked into a mirror.

Mr. Edwards, in the Nautical Almanack for 1787, gave the following instructions for making speculum metal.

The quality of the copper is to be tried by making a series of alloys with tin, in the proportion of 100 of the former to 47, to 48, to 49, and to 50 of the latter metal; whence the proportions of the whitest compound may be ascertained. Beyond the last proportion, the alloy begins to lose in brilliancy of fracture, and to take a bluish tint. Having determined this point, take 32 parts of the copper, melt, and add one part of brass and as much silver, covering the surface of the mixture with a little black flux; when the whole is melted, stir with a wooden rod, and pour in from 15 to 16 parts of melted tin (as indicated by the preparatory trials), stir the mixture again, and immediately pour it out into cold water. Then melt again at the lowest heat, adding for every 16 parts of the compound 1 part of white arsenic, wrapped in paper, so that it may be thrust down to the bottom of the crucible. Stir with a wooden rod as long as arsenical fumes rise, and then pour it into a sand mould. While still red hot, lay the metal in a pot-full of very hot embers, that it may cool very slowly, whereby the danger of its cracking or flying into splinters is prevented.

Having described the different alloys of copper and tin, I shall now treat of the method of separating these metals from each other as they exist in old cannons, damaged bells, &c. The process employed on a very great scale in France, during the Revolution, for obtaining copper from bells, was contrived by Fourcroy; founded upon the chemical fact that tin is more fusible and oxydizable than copper.

1. A certain quantity of bell metal was completely oxydized by calcination in a reverberatory furnace; the oxyde was raked out, and reduced to a fine powder.

2. Into the same furnace a fresh quantity of the same metal was introduced; it was

melted, and there was added to it one half of its weight of the oxyde formed in the first operation. The temperature was increased, and the mixture well incorporated; at the end of a few hours, there was obtained on the one hand copper almost pure, which subsided in a liquid state, and spread itself upon the sole of the hearth, while a compound of oxyde of tin, oxyde of copper, with some of the earthy matters of the furnace, collected on the surface of the metallic bath in a pasty form. These scoriæ were removed with a rake, and as soon as the surface of the melted copper was laid bare, it was run out. The scoriæ were levigated, and the particles of metallic copper were obtained after elutriation. By this process, from 100 pounds of bell-metal, about 50 pounds of copper were extracted, containing only one *per cent.* of foreign matters.

3. The washed scoriæ were mixed with $\frac{1}{8}$ their weight of pulverized charcoal; the mixture was triturated to effect a more intimate distribution of the charcoal; and it was then put into a reverberatory hearth, in which, by aid of a high heat, a second reduction was effected, yielding a fluid alloy consisting of about 60 parts of copper and 20 of tin; while the surface of the bath got covered with new scoriæ, containing a larger proportion of tin than the first.

4. The alloy of 60 of copper with 40 of tin was next calcined in the same reverberatory furnace, but with stirring of the mass. The air, in sweeping across the surface of the bath, oxydized the tin more rapidly than the copper; whence proceeded crusts of oxyde that were skimmed off from time to time. This process was continued till the metallic alloy was brought to the same standard as bell-metal, when it was run out to be subjected to the same operations as the metal of No. 1.

The layers of oxyde successively removed in this way were mixed with charcoal, and reduced in a *fourneau à manche*, or Scotch lead smelting furnace.

I shall not prosecute any further the details of this complicated process of Fourcroy; because it has been superseded by a much better one contrived by M. Bréant. He employed a much larger quantity of charcoal to reduce the scoriæ rich in tin; and increased the fusibility by adding crushed oyster-shells, bottle glass, or even vitrified scoriæ, according to the nature of the substance to be reduced; and he treated them directly in a reverberatory furnace.

The metal, thus procured, was very rich in tin. He exposed it in masses on a sloping hearth of a reverberatory furnace, where, by a heat regulated according to the proportions of the two metals in the alloy, he occasioned an eliquation or sweating out of the tin. Metallic drops were seen to transpire round the alloyed blocks or pigs, and, falling like rain, flowed down the sloping floor of the furnace; on whose concave bottom the metal collected, and was ladled out into moulds. When the alloy, thus treated, contained lead, this metal was found in the first portions that sweated out. The purest tin next came forth, while the last portions held more or less copper in solution. By fractioning the products, therefore, there was procured—

1. Tin with lead.
2. Tin nearly pure.
3. Tin alloyed with a little copper.

A spongy mass remained, exhibiting sometimes beautiful crystallizations; this mass, commonly too rich in copper to afford tin by liquation, was treated by oxydizement. In this manner, M. Bréant diminished greatly the reductions and oxydations; and therefore incurred in a far less degree the enormous waste of tin, which flies off with the draught of air in high and long-continued heats. He also consumed less fuel as well as labor, and obtained purer products of known composition, ready to be applied directly in many arts.

He treated advantageously in this manner more than a million of kilogrammes (1000 tuns) of scoriæ, for every 2 cwts. of which he paid 40 *centimes* (four-pence), while several million kilogrammes of much richer scoriæ had been previously sold to other refiners at 5 *centimes* or one *sous*.

I have said that the ancients made their tools and military weapons of Bronze. Several of these have been analyzed, and the results are interesting.

An antique sword, found in 1799, in the peat moss of the Somme, consisted of copper 87·47; tin 12·53, in 100 parts.

The bronze springs for the balistæ, according to Philo of Byzantium, were made of copper 97, tin 3.

Hard and brittle nails afforded by analysis, 92 of copper, and 8 of tin.

Of three antique swords found in the environs of Abbeville, one was found to consist of 85 of copper to 15 of tin. The nails of the handle of this sword were flexible; they were composed of copper 95, tin 5.

Another of the swords consisted of 90 of copper and 10 of tin; and the third, of 96 copper, with 4 tin.

A fragment of an ancient scythe afforded to analysis 92·6 copper, and 7·4 tin.

The process of coating copper with tin, exemplifies the strong affinity between the two metals. The copper surface to be tinned is first cleared up with a smooth sand-

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stone; then it is heated and rubbed over with a little sal ammoniac, till it be perfectly clean and bright: the tin, along with some pounded rosin, is now placed on the copper, which is made so hot as to melt the tin, and allow of its being spread over the surface with a dossil or pad of tow. The layer thus fixed on the copper is exceedingly thin; Bayen found that a copper pan, 9 inches in diameter and 3¼ inches deep, being weighed immediately before and after tinning, became only 21 grains heavier. Now as the area tinned, including the bottom, amounted to 155 square inches, 1 grain of tin had been spread over nearly 7½ square inches; or only 20 grains over every square foot.

Copper and Arsenic form a white-colored alloy, sometimes used for the scales of thermometers and barometers; for dials, candlesticks, &c. To form this compound, successive layers of copper clippings and white arsenic are put into an earthen crucible; which is then covered with sea salt, closed with a lid, and gradually heated to redness. If 2 parts of arsenic have been used with 5 of copper, the resulting compound commonly contains one tenth of its weight of metallic arsenic. It is white, slightly ductile, denser, and more fusible than copper, and without action on oxygen at ordinary temperatures; but, at higher heats, it is decomposed with the exhalation of arsenious acid. The white copper of the Chinese consists of 40·4 copper; 31·6 nickel; 25·4 zinc; and 2·6 iron. This alloy is nearly silver white; it is very sonorous, well polished, malleable at common temperatures, and even at a cherry red, but very brittle at a red-white heat. When heated with contact of air, it oxydizes, burning with a white flame. Its specific gravity was 8·432. When worked with great care, it may be reduced to thin leaves, and to wires as small as a needle. See German Silver, *infra.*

Tutenag, formerly confounded with white copper, is a different composition from the above. Keir says it is composed of copper, zinc, and iron; and Dick describes it as a short metal, of a grayish color, and scarcely sonorous. The Chinese export it, in large quantities, to India.

Copper, White, or *German silver.* M. Gersdorf, of Vienna, states, that the proportions of the metals in this alloy should vary according to the uses for which it is destined. When intended as a substitute for silver, it should be composed of 25 parts of nickel, 25 of zinc, and 50 of copper. An alloy better adapted for rolling, consists of 25 of nickel, 20 of zinc, and 60 of copper. Castings, such as candlesticks, bells, &c., may be made of an alloy, consisting of 20 of nickel, 20 of zinc, and 60 of copper; to which 3 of lead are added. The addition of 2 or 2½ of iron (in the shape of tin plate?) renders the packfong much whiter, but, at the same time, harder and more brittle.

Keferstein has given the following analysis of the genuine German silver, as made from the original ore found in Hildburghausen, near Suhl, in Henneberg:—

Copper	40·4
Nickel	31·6
Zinc	25·4
Iron	2·6
	100·0

Chinese packfong, according to the same authority, consists of 5 parts of copper, alloyed with 7 parts of nickel, and 7 parts of zinc.

The best alloy for making plummer blocks, bushes, and steps for the steel or iron gudgeons and pivots of machinery to run in, is said to consist of 90 parts of copper, 5 of zinc, and 5 of antimony.

A factitious protoxyde of copper, of a fine red color, may be made by melting together with a gentle heat, 100 parts of sulphate of copper, and 59 of carbonate of soda in crystals, and continuing the heat till the mass become solid. This being pulverized and mixed exactly with 15 parts of copper filings, the mixture is to be heated to whiteness, in a crucible, during the space of 20 minutes. The mass, when cold, is to be reduced to powder, and washed. A beautiful metallic pigment may be thus prepared, at the cost of 2*s.* a pound.

All the oxydes and salts of copper are poisonous; they are best counteracted by administering a large quantity of sugar, and sulphureted hydrogen water.

The following scientific summary of copper ores in alphabetical order may prove acceptable to many readers, amid the present perplexing distribution of the native metallic compounds in mineralogical systems.

1. *Arseniate of Copper.*

A. *Erinite,* rhomboidal arseniate of copper, micaceous copper, *kupferglimmer.* Emerald green: specific gravity 4·043; scratches calc-spar; yields water by heat; fusible at the blowpipe, and reducible into a white metallic globule. Soluble in nitric acid; the solution throws down copper by iron. It consists of arsenic acid 33·78; oxyde of copper 59·24; water 5; alumina 1·77. It is found in Cornwall, Ireland, Hungary.

B. *Liroconite;* octahedral arseniate of copper; lens ore, so called from the flatness of the crystal.. Blue; specific gravity 2·88; scratches calc-spar. It consists of arsenic acid 14; oxyde of copper 49; water 35. It is found in Huel-Mutrel, Huel-Gorland, Huel-Unity, mines in Cornwall.

C. *Olivenite;* right prismatic arseniate of copper; olive-ore. Dull green; specific gravity 4·28; scratches fluor; yields no water by heat; fusible at the blowpipe into a glassy bead, enclosing a white metallic grain. It consists of arsenic acid 45, oxyde of copper 50·62. It affords indications of phosphoric acid, which the analysts seem to have overlooked. It occurs in the above and many other mines in Cornwall.

D. *Aphanese.* Trihedral arseniate of copper. Bluish green, becoming gray upon the surface; specific gravity 4·28; scarcely scratches calc-spar; yields water with heat; and traces of phosphoric acid.

The fibrous varieties called wood copper, contain water, and resemble the last species in composition.

2. *Carbonate of Copper.*

A. *Azurite;* kupferlazur. Blue. Crystallizes in oblique rhomboidal prisms; specific gravity 3 to 3·83; scratches calc-spar, is scratched by fluor; yields water with heat, and blackens. Its constituents are, carbonic acid 25·5; oxyde of copper 69·1; water 5·4. The Chessy and Banat azurite is most profitably employed to make sulphate of copper.

B. *Malachite;* green carbonate or mountain green. Crystallizes in right rhomboidal prisms; specific gravity 3·5; affords water with heat, and blackens. It consists of carbonic acid 18·5; oxyde of copper 72·2; water 9·3.

C. *Mysorine;* anhydrous carbonate of copper. Dark brown generally stained green or red; conchoidal fracture; soft, sectile; specific gravity 2·62. It consists of carbonic acid 16·7; oxyde of copper 60·75; peroxyde of iron 19·5; silica 2·10. This is a rare mineral found in the Mysore.

3. *Chromate of Copper and Lead;* vauquelinite. Green of various shades; specific gravity 6·8 to 7·2; brittle; scratched by fluor; fusible at the blowpipe with froth and the production of a leaden bead. It consists of chromic acid 28·33; oxyde of lead 60·87; oxyde of copper 10·8. It occurs at Berezof in Siberia along with chromate of lead.

4. *Dioptase;* silicate of copper; emerald copper. Specific gravity 3·3; scratches glass with difficulty; affords water with heat, and blackens; infusible at the blowpipe. It consists of silica 43·18; oxyde of copper 45·46; water 11·36. This rare substance comes from the government of Kirgis.

The silicate of Dillenberg is similar in composition.

5. Gray copper ore called Panabase, from the number of metallic bases which it contains; and Fahlerz. Steel gray; specific gravity 4·79 to 5·10; crystallizes in regular tetrahedrons; fusible at the blowpipe, with disengagement of fumes of antimony and occasionally of arsenic; swells up and scorifies, affording copper with soda flux. Is acted upon by nitric acid with precipitation of antimony; becomes blue with ammonia; yields a blue precipitate with ferrocyanide of potassum; as also indications frequently of zinc, mercury, silver, &c. Its composition which is very complex is as follows: sulphur 26·83; antimony 12·46; arsenic 10·19; copper 40·60; iron 4·66; zinc 3·69; silver 0·60 Some specimens contain from 5 to 31 per cent. of silver. The gray copper ores are very common; in Saxony; the Hartz; Cornwall; at Dillenberg; in Mexico, Peru, &c. They are important on account both of their copper and silver. *Tennantite* is a variety of Fahlerz. It occurs in Cornwall. Its constituents are, sulphur 28·74; arsenic 11·84; copper 45·32; iron 9·26.

6. *Hydrated silicate of Copper;* or Chrysocolla. Green or bluish green; specific gravity 2·03 to 2·16; scratched by steel; very brittle; affords water with heat, and blackens; is acted upon by acids, and leaves a silicious residuum. Solution becomes blue with ammonia. Its constituents are silica 26; oxyde of copper 50; water 17; carbonic acid 7.

7. *Muriate of Copper.* Gtakamite; green; crystallizes in prisms; specific gravity 4·43. Its constituents are, chlorine 15·90; copper 14·22; oxyde of copper 54·22; water 14·16; oxyde of iron 1·50. The green sand of Peru, collected by the inhabitants of Atakama, is this substance in a decomposed state.

8. *Oxyde of Copper.*

A. Black, or Melaconise; a black earthy looking substance found at Chessy and other places. It is deutoxyde of copper.

B. Protoxyde or red oxyde of copper; ziegelerz. Crystallizes in the regular octahedron; specific gravity 5·69; scratches calc-spar; fusible at the blowpipe into the black oxyde; and reducible in the smoke of the flame to copper; acted upon by nitric acid with disengagement of nitrous gas; solution is rendered blue by ammonia. Its constituents are oxygen 11·22; copper 88·78. It occurs near Chessy, and upon the eastern slope of the Altai mountains.

9. *Phosphate of Copper.* Dark green; crystallizes in octahedrons; specific gravity 3·6 to 3·8; scratches calc-spar; yields water with heat; and affords metallic copper

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with soda flux; acted on by nitric acid. Its constituents are, phosphoric acid 28·7, oxyde of copper 63·9; water 7·4. It occurs at the mines of Libethen in Hungary.

10. *Pyritous Copper;* Kupferkies; a metallic looking substance, of a bronze-yellow color, crystallizing in octahedrons which pass into tetrahedrons; specific gravity 4·16; fusible at the blowpipe into beads attractable by the magnet, and which afterwards afford copper with a soda flux; soluble in nitric acid; solution is rendered blue by ammonia, and affords an abundant precipitate of iron. Its composition is, sulphur 36; copper 34·5; iron 30·5; being a combined sulphuret of these two metals. This is the most important metallurgic species of copper ores. It occurs chiefly in primitive formations, as among gneiss and mica slate, in veins, or more frequently masses, in very many parts of the world—Cornwall, Anglesea, Wicklow, &c. It is found among the early secondary rocks, in Shetland, Yorkshire, Mannsfeldt, &c. The finest crystallized specimens come from Cornwall, Derbyshire, Freyberg, and Saint Marie-aux-Mines in France.

11. *Seleniate of Copper;* Berzeline. Is of metallic aspect; silver white; ductile; fusible at the blowpipe into a gray bead, somewhat malleable; is acted upon by nitric acid; consists of selenium 40; copper 64.

12. *Sulphate of Copper;* Cyanose. Blue; soluble, &c. like the artificial sulphates, which see.

Brochantite is a subsulphate of copper, observed in smal crystals at Ekaterinenbourg in Siberia.

13. *Sulphuret of Copper;* Kupferglanz. Of a steel gray metallic aspect; crystallizes in rhomboids; specific gravity 5·69; somewhat sectile, yet brittle; fusible with intumescence at the blowpipe, and yields a copper bead with soda; soluble in nitric acid; becomes blue with ammonia, but lets fall scarcely any oxyde of iron. Its constituents are sulphur 19; copper 79·5; iron 0·75; silica 1·00. It occurs in small quantities in Cornwall, &c.

The chemical preparations of copper which constitute distinct manufactures are, Blue or Roman vitriol; for which see *Sulphate of Copper;* Scheele's green and Schweinurth green, Verditer, and Verdigris. See these articles in their alphabetical places.

The copper mines, now so important, were so little worked until a recent period, that in 1799 we are told in a Report on the Cornish mines, "it was not until the beginning of the last century that copper was discovered in Britain." This is not correct for in 1250, a copper mine was worked near Keswick in Cumberland. Edward III. granted an indenture to John Ballanter and Walter Bolbolter, for working all "mines of gold, silver, and copper;" but that the quantity found was very small is proved from the fact that Acts of Parliament were passed in the reigns of Henry VIII. and Edward VI. to prevent the exportation of brass and copper, "lest there should not be metal enough left in the kingdom, fit for making guns and other engines of war, and for household utensils;" and in 1665 the calamine works were encouraged by the government, as "the continuing these works in England will occasion plenty of rough copper to be brought in."

At the end of the seventeenth century some "gentlemen from Bristol made it their business to inspect the Cornish mines, and bought the copper for 2*l.* 10*s.* per ton, and scarce ever more than 4*l.* a ton."

In 1700, one Mr. John Costor introduced an hydraulic engine into Cornwall, by which he succeeded in draining the mines, and "he taught the people of Cornwall also a better way of assaying and dressing the ore."

The value and importance of copper mines since that period has been regularly increasing. During a term of about 30 years 220 mines have sold their ores at the public sales. The following table (p. 490) from a report by Sir Charles Lemon, Bart. M. P., represents the progress of copper mining, from 1771 to 1837.

The produce of the copper mines of Cornwall since 1845, has been as follows.

Years.	Ore in Tons.	Copper in Tons.	Money Value. £	s.
1845	162,557	12,883	919,934	6
1846	150,431	11,851	796,182	6
1847	155,985	12,754	889,287	0
1848	147,701	12,422	720,090	0
1849	146,326	11,683	763,614	0
1850	155,025	12,254	840,410	0

Years.	Tons of Ore.	Tons of Copper.	Total Value of Ore.	Standard Value per Ton.
			£	
1771	27,896	3,347	189,609	81
1780	24,433	2,932	171,231	83
1799	51,273	4,223	469,664	121
1800	55,981	5,187	550,925	133
1802	53,937	5,228	445,094	111
1805	78,452	6,234	864,410	170
1808	67,867	6,795	495,303	100
1809	76,245	6,821	770,028	143
1812	71,547	6,720	549,665	111
1814	74,322	6,369	627,501	130
1816	77,334	6,697	447,959	98
1818	86,174	6,849	686,005	155
1821	98,426	8,514	605,968	103
1825	107,454	8,226	726,353	124
1827	126,700	10,311	745,178	106
1831	146,502	12,218	817,740	100
1837	140,753	10,823	908,613	119

With the improvements in the construction of the steam-engine, the facilities for working the mines have been increased, The first steam engine employed in the county was set to work at Huel Vor tin mines, near Helstone, in 1713, by Newcomen; but it was not until the reconstruction of the engine was effected by Watt that steam power was generally employed for draining the mines. The rapid advance made by Cornish engineers in the perfection of their engines will be seen by the following return of the duty, that is, the performance of each, which is reckoned by the number of millions of pounds lifted a foot high by the consumption of a bushel of coals:—

Name of Mine.	Highest Duty.
Stray Park, 1813 - - - - -	29,000,000
Dolcoath, 1816 - - - - -	40,000,000
Consolidated Mines, 1822 - - - -	44,000,000
Consolidated Mines, 1827 - - - -	67,000,000
Fowey Consols, 1834 - - - - -	97,000,000
United Mines, 1842 - - - - -	108,000,000

Copper exported:—

Years ending	Wrought.	Unwrought.		Total.
	To all parts.	To India.	To all parts.	To all parts.
	Tons.	*Tons.*	*Tons.*	*Tons.*
5th January, 1825 - - -	—	—	960	
1826 - - -	—	—	½	
1827 - - -	—	—	130	
1828 - - -	—	—	1329	
1829 - - -	—	—	1079	
1830 - - -	5327	1801	2682	8,009
1831 - - -	6172	2317	3150	9,322
1832 - - -	5171	2423	3714	8,885
1833 - - -	5855	2312	4569	10,424
1834 - - -	5417	1769	4019	9,436
1835 - - -	4787	2104	5283	10,072
1836 - - -	5948	1993	5935	11,883
1837 - - -	6105	1588	3909	10,014

* Supplement to the Mining Journal, Feb. 28, 1838.

Statistics of Copper for Cornwall in 1837.—The total quantity of ore sold was 142,089 tons (of 21 cwts.) yielding an average produce of eight per cent.; the quantity of fine copper being 11,209 tons 1 cwt.; and the average price of the ore 5*l.* 15*s.* 6*d.*; the total amount of the sales for the twelve months being 822,516*l.* The standard upon the 5th of January was 127*l.* 16*s.*; this was the highest for the year. Upon the 22d of June it was at the lowest, being only 93*l.* 18*s.* It went up again to 120*l.* 10*s.* upon the 5th of October; but declined with some slight fluctuation to 107*l.* 18*s.* upon the 28th of December. The largest quantity sold at any one ticketing was 4670 tons, upon the 4th of May; and the smallest 1088, upon the 17th of August. The highest produce was nine and five eighths per cent. upon the 13th of July; and the lowest, seven, upon the 26th of January. The greatest weekly total was 25,887*l.*, upon the 2d of November, and the least 5694*l.* upon the 17th of August. The average sum per week was 15,817*l.**

Quantity of Copper produced in the several districts of Great Britain and Ireland:—

With Ores from—	1828.	1829.	1830.	1831.	1832.
	Tons.	Tons.	Tons.	Tons.	Tons.
Cornwall - - - -	1966	9763	10,890	12,218	12,099
Devonshire - - - -	434	318	368	312	249
Other parts of England - - -	71	36	10	31	42
Island of Anglesea - - -	738	901	815	809	852
Other parts of Wales - - -	259	172	237	123	237
Ireland - - - - -	706	790	768	972	974
Isle of Man - - - -	—	4	9	15	12
Total copper from the ores of the United Kingdom - -	12,193	11,994	13,097	14,480	14,465
Copper smelted from Foreign ores -	—	30	124	100	56
General total - - -	12,169	12,024	13,221	14,580	14,541

Table of the produce of Copper Ores and fine Metal in Cornwall, from 1800 to 1830.

Years.	Ores.	Metal.		Value of Ore.			Metal.	Average Standard.		
	Tons of 21 *Cwts.*	*Tons.*	*Cwt.*	£	*s.*	*d.*	*Per Cent. of Ore.*	*Price per Ton.* £	*s.*	*d.*
1800	55,981	5187	0	550,925	0	0	$9\frac{1}{4}$	133	3	6
1801	56,611	5268	0	476,331	0	0	$9\frac{1}{4}$	117	8	0
1802	53,937	5228	15	445,094	0	0	$9\frac{5}{8}$	110	18	0
1804	64,637	5374	18	507,840	11	0	$8\frac{3}{3}$	136	5	0
1806	79,269	6863	10	730,845	6	0	$8\frac{5}{8}$	138	5	0
1808	67,867	6795	13	495,303	10	0	10	100	7	0
1810	66,048	5682	19	570,035	8	0	$8\frac{1}{2}$	132	5	0
1812	71,547	6720	7	549,665	6	0	$9\frac{3}{8}$	111	0	0
1814	74,322	6369	13	627,501	10	0	$8\frac{1}{2}$	130	12	0
1816	77,334	6697	4	447,959	17	0	$8\frac{5}{8}$	98	13	0
1818	86,174	6849	7	686,005	4	0	$7\frac{7}{8}$	134	15	0
1820	91,473	7508	0	602,441	12	0	$8\frac{1}{8}$	113	15	0
1822	104,523	9140	8	663,085	13	0	$8\frac{3}{4}$	104	0	0
1824	99,700	7823	15	587,178	0	0	$7\frac{7}{8}$	110	0	0
1826	117,308	9026	12	788,971	15	0	$7\frac{5}{8}$	123	3	0
1828	130,366	9921	1	756,174	16	0	$7\frac{5}{8}$	112	7	0
1829	124,502	9656	10	717,334	0	0	$7\frac{3}{4}$	109	14	0
1830	143,296	11,224	19	887,900	0	0	$7\frac{3}{4}$	114	4	0
1834 1835	150,617	12,271	14	893,402	15	0	$8\frac{1}{8}$	106	11	0

The following table, extracted from the *London Mining Journal*, July 18, 1852 gives the comparative averages of the weekly sales of Copper Ores for ten years, to the second week in July, 1852, at the Royal Hotel, Truro, Cornwall.

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* Mining Review, Feb. 28, 1838.

Year.	Tons.	Produce.	Amount. £	s.	d.	Standard. £	s.	Price of Copper Ore. £	s.	Price of Copper Cake. £	s.	d.
1842	2196	6¾	9,676	8	6	108	7	67	13	92	0	0
1843	2986	8	16,788	13	6	105	5	70	14	82	0	0
1844	2021	6¾	13,012	11	6	107	3	66	6	83	0	0
1845	3205	7½	18,254	5	6	107	18	72	15	88	0	0½
1846	2289	8½	12,156	6	6	98	13	65	0	93	9	6
1847	2386	8¼	14.184	19	0	105	10	72	2	98	10	1
1848	2372	9¼	11,039	11	0	80	2	54	19	88	0	0½
1849	2538	8¾	13.913	5	6	94	9	62	18	79	0	0½
1850	2490	9¼	15,395	2	6	97	14	67	13	84	0	0
1851	2541	8¼	14,015	14	6	99	14	66	10	84	0	84

An account of the quantities of Foreign wrought and unwrought Copper, and Copper Ore, imported and exported, and of British wrought and unwrought Copper exported from the United Kingdom; together with the quantities and value of Copper Ore smelted in Cornwall and Swansea, and the quantity of Copper produced in those places; and in the county of Devon; together with the market prices of sheet and cake Copper. in the year ending 5th January, 1835:—

	Quantity.	Value.		
		£	s.	d.
Foreign Copper imported:				
Unwrought in bricks or pigs, rose and cast copper, *Cwts.*	5,389			
Part wrought, viz., bars, rods, or ingots, hammered or raised - - - - - - - - -	1,968			
Wrought plates and coin - - - - - -	2			
— old for re-manufacture - - - - -	493			
Copper ore Foreign - - - - - - -	278,900			
Manufactures of copper, entered by weight - -	650			
— entered at value - -	—	5,353	0	0
Foreign copper exported, viz:—				
Unwrought, in bricks and pigs, rose and cast copper - - - - - - - - - - *Cwts.*	6,898			
Part wrought, viz., bars, rods, or ingots, hammered or raised - - - - - - - - -	2,013			
Old, fit only for re-manufacture - - - - -	265			
Smelted in the United Kingdom from foreign ore -	55,456			
Manufactures of copper, entered by weight - -	650			
— entered at value - -	—	112	0	0
BRITISH COPPER.				
Exported, unwrought, in bricks and pigs - - - *Cwts.*	63,252			
— wrought sheets, nails, &c. - - - -	103,433			
— wire - - - - - - - -	56			
— of other sorts - - - - -	15,197			
Total of British copper exported - - - - -	182,225			
Ores sold in Cornwall:—				
Quantity of ore - - - - - - - - *Tons*	150,617			
Value of ditto - - - - - - - - -	—	893,403	0	0
Quantity of metal - - - - - - - *Tons*	12,270			
Standard - - - - - - - - - -	—	106	11	0
Produce per cent. - - - - - - - -	8½			
Ores sold, &c. in Swansea:—				
Quantity of ore - - - - - - - - *Tons*	28,746			
Value of ditto - - - - - - - - -	—	223,958	0	0
Quantity of metal - - - - - - - *Tons*	2,832			
Standard - - - - - - - - - -	—	101	18	0
Produce per cent. - - - - - - - -	9⅞			
Copper sold in Devonshire ore - - - *Tons*	5,114			
Copper sold in Devonshire metal - - - *Tons*	455			
Total quantity of copper raised in the United Kingdom, exclusive of Anglesea and Staffordshire, and deducting 1083 tons of metal, value 88,207*l.*, the produce of 4985 tons of foreign ore sold at Swansea, included above,	14,474			

Quantity of copper ore raised in Cornwall in the year 1846, 150,431 tons; value of, 796,182*l.* 6*s.* 6*d.*

Quantity raised in the year 1847, 155,985 tons; value of, 889,287*l.* 0*s.* 6*d.*

Quantity of metallic copper produced in the former year, 11,850 tons; in the latter 12,754.

Produce per cent. 7⅞ and 8½ respectively. *See* METALLIC STATISTICS.

Description.	Imports.		Entries for Consumption.		Exports, Foreign		Exports, British.		Duty on Imports.	
	1850.	1851.	1850.	1851.	1850.	1851.	1850.	1851.	1850.	1851.
Copper ore and regulus, tons.	45,862	42,476	45,705	42,219	- -	- -	- -	- -	£ 2,285	£ 211
unwrought and part wrought, cwts. -	97,621	106,064	83,626	103,500	16,685	25,746	- -	- -	523	647
bricks and pigs, cwts. -	- -	- -	- -	- -	- -	- -	154,678	111,939		
sheets, nails, &c. (including mixed or yellow metal for sheathing), cwts. - -	- -	- -	- -	- -	- -	- -	263,008	216,075		
wrought of other sorts, cwts. - - -	- -	- -	- -	- -	- -	- -	8,468	19,939		

COPPERING IRON AND ZINC. The great advantages which would arise from perfecting a plan whereby the easily oxidizable metals, such as iron and zinc, could be coated with copper at a cheap rate, induced Messrs. Elsner & Philip, of Berlin, to undertake a series of experiments, to ascertain if such could not be effected more economically than by employing the cyanuret of potassium, and in this they have been successful. For coating iron the article must be well cleaned in rain or soft water, and rubbed before immersing it in the solution, which may be either chloride of potassium, chloride of sodium, with a little caustic ammonia added, or tartrate of potash, with a small portion of carbonate of potash. At the extremity of the wire, in connection with the copper, or negative pole of the battery, is fixed a thin flattened copper plate, and the article to be coated is attached to the wire from the zinc, or positive pole, and both are then immersed in the exciting solution, the copper plate only partially. The liquid should be kept at a temperature of from 15° to 20° Centigrade, and the success of the operation depends greatly on the strength and uniformity of the galvanic current. When the chlorides are employed, the coating is of a dark, natural copper color; and with tartrate of potash, it assumes a red tinge, similar to the red oxide of copper. When sufficiently covered, the article is rubbed in sawdust, and exposed to a current of warm air to dry, when they will take a fine polish, and resist all atmospheric influence. In coating zinc with copper, the same general principles will apply as for iron, only observing that, in proportion to the size of the article, the galvanic current must be less powerful for zinc. The surfaces must be perfectly smooth, and for this reason it is well to rub them thoroughly with fine sand, and polish with a brush. Tartrate of potash is the best existing liquid for coating zinc. By very simple means large articles in iron and zinc may be coated with copper by the above cheap chemical solutions, which could not, at any former period, be effected from the high price of cyanuret of potassium.

COPPER MEDALS AND MEDALLIONS may be readily made in the following way:—Let black oxide of copper, in fine powder, be reduced to the metallic state, by exposing it to a stream of hydrogen, in a gun-barrel, heated barely to redness. The metallic powder thus obtained is to be sifted, through crape, upon the surface of the mould, to the thickness of ½ or ⅓ of an inch, and is then to be strongly pressed upon it, first by the hand, and lastly by percussion with a hammer. The impression thus formed is beautiful; but it acquires much more solidity by exposure to a red heat, out of contact with air. Such medals are said to have more tenacity than melted copper, and to be sharply defined.

M. Bœttger proposes the following improvement upon the above plan of Mr. Osann:—He prepared the powder of copper easier and of better quality, by precipitating a boiling hot solution of sulphate of copper, with pieces of zinc, boiling the metallic powder thus obtained with dilute sulphuric acid for a little, to remove all traces of the zinc or oxide, washing it next with water, and drying it in a tubulated retort by the heat of a water bath, while a stream of hydrogen is passed over it. This cuprous precipitate possesses so energetic an affinity for oxygen, that it is difficult to prevent its passing into the state of orange oxide. If it be mixed with one half its atomic weight of precipitated sulphur, and the two be ground together, they combine very soon into sulphuret of copper with the evolution of light.

COPPER, PURIFYING.—Copper may be purified by melting 100 parts of it with 10 parts of copper scales (black oxide), along with 10 parts of ground bottle-glass or other flux. Mr. Lewis Thompson, who received a gold medal from the Society of Arts for this invention, says, that after the copper has been kept in fusion for half an hour, it will be found at the bottom of the crucible perfectly pure; while the iron, lead, arsenic, &c., with which this metal is usually contaminated, will be oxidized by the scales, and will dissolve in the flux, or be volatilized. Thus he has obtained perfectly pure copper from brass, bell-metal, gun-metal, and several other alloys, containing from 4 up to 50 per cent. of iron, lead, antimony, bismuth, arsenic, &c. The scales of copper are cheap, being the product of every large manufactory where that metal is worked.

COPPERAS. (*Couperose verte*, Fr.: *Eisenvitriol*, Germ.) Sulphate of iron.

COPROLITES, OR FOSSIL MANURE. Wherever there is an out-cropping of the upper green sand (the stratum in which coprolites are found)—and it extends a considerable distance around Cambridge—there these peculiar nodules may be met with. And this, the surface bottom of an ancient deep sea, appears to have been the receptacle of the bones and fæcal matter of its inhabitants for a long period, which matter is now, by the united penetrating researches of the chemist and geologist, brought to light, as containing the fertilizing principle and pabulum of vegetable life, verifying the axiom of chemistry, that nothing is lost in organic atoms, and that the refuse of former ages, in an indirect manner, produces the food of the present. The parish of Barnwell contains an extensive area of these coprolites or fossil dung.

The appearance of these nodules is in shape various; generally a hard, black, water-worn looking stone, with excrescences; some with convoluted marks, bearing the impress of the intestine, and rounded off at the extremities; the surface of all exhibiting lines from the decomposition of its more destructible component parts. Portions of coral, ammonites, crustacea, sponges, &c., may be found in the agglutinated mass. They vary in size from a small bird's egg to masses the size of a fist. A large selection from our own, as well as from distant localities—the lias of Lyme, the chalk of Farnham, the slate of Newhaven, and the crag of Suffolk—are open for the inspection of those interested in most geological collections.

The process which they go through to render them available for use is as follows:—After being selected from the soil, they are well-washed by rotary machinery erected on the spot, and then conveyed by rail to the manufactory, where they are ground to a very fine powder; an operation, from their hardness, of no small difficulty, vertical granite and buhr stones being required. The powder is mixed with about an equal portion by weight of strong sulphuric acid. This is, I believe, a part of the process used in the manufactory of Mr. Lawes, who produces a very superior article, and to whom we are much indebted for his early attention to supply the increasing demand for phosphates as artificial manures, and who has been supplied with thousands of tons from digging over a four-acre field at Walton, in Suffolk, the subsoil of which was crag, producing to the farmer a much richer harvest than grain at the present free-trade prices. In an article varying, as it necessarily must, from extraneous matter, the component parts materially differ. The following analysis may be taken as an average of their composition, 100 parts containing—

Earthy phosphates	61
Carbonate of lime and iron	24
Insoluble	12
Moisture	3
	100

Mr. Lawes, from a sample from the same locality, made 7 more parts of phosphates, and Mr. Potter 4 less, than the above analysis.

There is a prevalent idea that these coprolites are almost the same as guano. This is a great mistake; for although our own production yields a larger proportion of the phosphates, it is devoid of salts of urea and ammonia, which, in combination with the phosphates, increases to a considerable extent the fertilizing principle for which that foreign article is so celebrated. It has been the object of artificial manures to supply synthetically the composition of guano at a much reduced rate.

In respect to the value of coprolites in Suffolk, besides giving employment at the slack season to many idle hands, a bonus has been given for the right of royalty over the soils, and 5*s.* per ton is paid the proprietor for all raised. This, with labor, washing—a troublesome and tedious process—and rail charges for delivery in London, costs from 35*s.* to 40*s.* per ton.

To show the comparative value of the different substances containing the phosphates, and that of guano, an analysis of a good sample is here given, and that of the phosphates and carbonate of lime in various bones. That portion contained in the fossil remains of bones and coprolite is a beautiful illustration of the goodness of the Great Author of nature—remains which, after being interred thousands of years, are by the labors of man brought again into action, that their elementary parts may be again separated and made subservient to his uses.

Analysis of Guano from Peru.

Urate and salts of ammonia	34·05
Various phosphates	37·04
Carbonate of lime	1·65
Soda and potash	8·92
Silex	4·28
Water and indefinite organic matter	14·06
	100·00

Comparative Analysis of Bones.

	Phosphates.	Carbonate of Lime.
Recent human bones	81·09	10·03
Ancient ditto from Roman *tumulus*	76·38	10·13
Fossil bone from the crag	60·02	18·00
Recent ox bones	57·35	3·85
Sheep bones	80.00	19·03
Bones of the hen	88·09	10·04
" frog	95·02	2·04
" fishes	91·09	5·03

The following two samples from the coast of Suffolk were found to consist of—

	I.	II.
Water with a little organic matter	4·00	3·560
Salts soluble in water (chloride of sodium and sulphate of soda)	traces	traces
Carbonate of lime	10·280	8·959
do. magnesia	a trace	a trace
Sulphate of lime	distinct traces	0·611
Phosphate of lime (3 Ca O, PO^5)	70·920=PO^5 32·765	69·099=PO^5 31·924
do magnesia	traces only	traces
Perphosphate of iron (2 Fe^2 O^3, 3 PO^5)	6·850=PO^5 3·244	8·616=PO^5 4·081
Phosphate of alumina (2 Al^2 O^3, 3 PO^5)	1.550=PO^5 0·870	2·026=PO^5 1·158
Oxide of Manganese	traces	traces
Fluoride of calcium	0·608	0·804
Silicic acid colored red by a little undecomposed silicate of iron	5.792	6·309
	100.000=PO^5 36·889	100·000=PO^5 37.16

I. Fifty grains of the first specimen, in fine powder, when burnt with potash lime, furnished 0·20 gr. of platino-chloride of ammonium, which is equivalent to 0·0254 per cent. of nitrogen.

It is said that the coprolites which Mr. Lawes employs in the manufacture of his well-known "Coprolite manure," are obtained from the Suffolk coast, and are similar in character to the above.

In an excellent paper "On the Phosphoric Strata of the Chalk Formations," published in the first number of the Journal of the Royal Agricultural Society of England for the last year, Mr. Way observes, that he has found the coprolites from this district to contain from 52 to 54 per cent. of bone-earth phosphate; and that Dr. Gilbert had informed him, that in several analyses which he had made of samples taken from several tons of the ground coprolites, he had found the proportion of phosphate of lime to vary between 55 and 57 per cent. Mr. Nesbit (Quart. Journ. of Chem. Soc. Part III. p. 235) found from 22·30 to 28·74 per cent. of phosphoric acid, which is equivalent to from 48·31 to 59·07 of tribasic phosphate, in those from the tertiary deposits of this county.

II. This one was brought from the same part of the coast as the preceding; but differed from them in its irregularity of form, and in exhibiting imperfect evidences of a bony structure. The specific gravity it was found impossible to determine, on account of the numerous air cavities it contained.

Analysis showed it to possess the following per centage composition:—

Water driven off at from 300° to 350° F.	2·600	
do. and organic matters expelled at a red heat	9·000	
Chloride of sodium, &c.		evident traces
Carbonate of lime	39·500	
do. magnesia	0·520	
Sulphate of lime		distinct traces
Phosphate of lime (tribasic)	15·860	=PO^5 5·287
do. magnesia		traces
Perphosphate of iron	9·200	=PO^5 4·358
Phosphate of alumina	4·708	=PO^5 2·764
Peroxide of iron		none
Alumina	6·212	
Fluoride of calcium	1·698	
Silicic acid	10·601	
	99·899	=PO^5 12.409

The proportion of nitrogen in this specimen was not estimated.

III. This coprolite was discovered in the lias strata of Lyme Regis.

It was rather large, being above 9 ozs. in weight, was of a grayish color, and when broken exhibited some traces of crystalline structure. It was considerably softer than either of the preceding, and furnished a grayish-white powder. Many scales of different extinct fishes, and other organic remains, were to be perceived on the external surface; the greater proportion of them appeared to belong to a species of fish which is known to ichthyologists by the name of *Pholidophorus limbatus.* Its specific gravity was about 2·644 or 2·700, and the composition per cent. was as follows:—

	I.	II.	Mean.	
Water driven off at from 300° to 350° F.	2·560	2·668	2·6140	
Water and organic matters expelled at a red heat	3·680	3·456	3.5680	
Chloride of sodium, with some sulphate of soda	traces	traces	traces	
Carbonate of lime	23·640	23·708	23·6740	
do. of magnesia	none	none	none	
Sulphate of lime	1·740	1·801	1·7705	
Phosphate of do. (tribasic)	60·726	60·813	60·7695	=PO^5 28·047
do. magnesia	a little	a little	a little	
Perphosphate of iron	3·980	4·135	4·0575	=PO^5 1·922
Phosphate of alumina	a little	a little	a little	
Peroxide of iron	2·094	1·894	1·9940	
Alumina	none	none	none	
Silicic acid, with fluoride of calcium and loss	1·580	1·525	1·5525	
	100·000	100·000	100·0000	=PO^5 29·969*

The proportion of nitrogen in this specimen was rather large, being 0·0826 per cent.—*Thornton J. Herapath.*

CORAL (*Corail*, Fr.; *Koralle*, Germ.) is a calcareous substance, formed by a species of sea polypus, which construct in concert immense ramified habitations, consisting of an assemblage of small cells, each the abode of an animal. The coral is, therefore, a real polypary, which resembles a tree stripped of its leaves. It has no roots, but a foot not unlike a hemispherical skull-cap, which applies closely to every point of the surface upon which it stands, and is therefore difficult to detach. It merely serves as a basis or support to the coral, but contributes in no manner to its growth, like the root of an ordinary tree, for detached pieces have been often found at the bottom of the sea in a state of increase and reproduction. From the above base a stem, usually single, proceeds, which seldom surpasses an inch in diameter, and from it a small number of branches ramify in very irregular directions, which studded over with cells, each containing an insect. The polypi, when they extend their arms, feelers, or *tentacula*, resemble flowers, whence, as well as from the form of the coral, they were classed among vegetable productions. They are now styled zoophites by the writers upon Natural History.

The finest coral is found in the Mediterranean. It is fished for upon the coasts of Provence, and constitutes a considerable branch of trade at Marseilles. The coral is attached to the submarine rocks, as a tree is by its roots, but the branches, instead of growing upwards, shoot downwards towards the bottom of the sea; a conformation favorable to breaking them off and bringing them up. For this kind of fishing, eight men, who are excellent divers, equip a felucca or small boat, called commonly a coralline. They carry with them a large wooden cross, with strong, equal, and long arms, each bearing a stout bag-net. They attach a strong rope to the middle of the cross, and let it down horizontally into the sea, having loaded its centre with a weight sufficient to sink it. The diver follows the cross, pushes one arm of it after another into the hollows of the rocks, so as to entangle the coral in the nets. Then his comrades in the boat pull up the cross and its accompaniments.

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* In the first of these analyses, the phosphoric acid was estimated by M. Schulze's method, as perphosphate of iron; in the second, as phosphate of lead.

Coral fishing is nearly as dangerous as pearl fishing, on account of the number of sharks which frequent the seas where it is carried on. One would think the diving-bell in its now very practicable state might be employed with great advantage for both purposes.

Coral is mostly of a fine red color, but occasionally it is flesh-colored, yellow, or white. The red is preferred for making necklaces, crosses, and other female ornaments. It is worked up like precious stones. See LAPIDARY.

CORK (*Liége*, Fr.; *Kork*, Germ.) is the bark of the *quercus liber*, Linn., a species of oak-tree, which grows abundantly in the southern provinces of France, Italy, and Spain. The bark is taken off by making coronal incisions above and below the portions to be removed; vertical incisions are then made from one of these circles to another, whereby the bark may be easily detached. It is steeped in water to soften it, in order to be flattened by pressure under heavy stones, and next dried at a fire which blackens its surface. The cakes are bound up in bales and sent into the market.

There are two sorts of cork, the white and the black; the former grows in France and the latter in Spain. The cakes of the white are usually more beautiful, more smooth, lighter, freer from knots and cracks, of a finer grain, of a yellowish gray color on both sides, and cut more smoothly than the black. When this cork is burned in close vessels it forms the pigment called *Spanish black*.

This substance is employed to fabricate not only bottle corks, but small architectural and geognostic models, which are very convenient from their lightness and solidity.

The cork-cutters divide the boards of cork first into narrow fillets, which they afterwards subdivide into short parallelopipeds, and then round these into the proper conical or cylindrical shape. The bench before which they work is a square table, where 4 workmen are seated, one at every side, the table being furnished with a ledge to prevent the corks from falling over. The cork-cutter's knife is a broad blade, very thin, and fine edged. It is whetted from time to time upon a fine-grained dry whetstone. The workman ought not to draw his knife edge over the cork, for he would thus make misses, and might cut himself, but rather the cork over the knife edge. He should seize the knife with his left hand, rest the back of it upon the edge of the table, into one of the notches made to prevent it from slipping, and merely turns its edge sometimes upright and sometimes to one side. Then holding the squared piece of cork by its two ends, between his finger and his thumb, he presents it in the direction of its length to the edge; the cork is now smoothly cut into a rounded form by being dexterously turned in the hand. He next cuts off the two ends, when the cork is finished and thrown into the proper basket alongside, to be afterwards sorted by women or boys.

Of late years a much thicker kind of cork boards have been imported from Catalonia, from which longer and better corks may be made. In the art of cork-cutting the French surpass the English, as any one may convince himself by comparing the corks of their champagne bottles with those made in this country.

Cork, on account of its buoyancy in water, is extensively employed for making floats to fishermen's nets, and in the construction of life-boats. Its impermeability to water has led to its employment for inner soles to shoes.

When cork is rasped into powder, and subjected to chemical solvents, such as alcohol, &c., it leaves 70 per cent. of an insoluble substance, called *suberine*. When it is treated with nitric acid, it yields the following remarkable products: — White fibrous matter 0·18, resin 14·72, oxalic acid 16·00, suberic acid (peculiar acid of cork) 14·4 in 100 parts.

Machine cork-cutting. — A patent was obtained some years ago by Sarah Thomson for this purpose. The cutting of the cork into slips is effected by fixing it upon the sliding bed of an engine, and bringing it, by a progressive motion, under the action of a circular knife, by which it is cut into slips of equal widths. The nature or construction of a machine to be used for this purpose may be easily conceived, as it possesses no new mechanical feature, except in its application to cutting cork. The motion communicated to the knife by hand, steam, horse, or other power, moves at the same time the bed also, which carries the cork to be cut.

The second part of the invention, viz., that for separating the cork into square pieces, after it has been cut into slips as above, is effected by a moving bed as before, upon which the slips are to be placed and submitted to the action of a cutting lever, which may be regulated to chop the cork into pieces of any given length.

The third part of the invention, viz., that for rounding or finishing the corks, consists of an engine to which is attached a circular knife that turns vertically, and a carriage or frame upon its side that revolves on its axle horizontally.

This carriage or frame contains several pairs of clamps intended respectively to hold a piece of the square cut cork by pressing it at the ends, and carrying it lengthways perpendicularly; which clamps are contrived to have a spindle motion, by means of a pinion at the lower end of their axles, working into a spur-wheel.

The machinery, thus arranged, is put in motion by means of bands and drum-wheels, or any other contrivance which may be found most eligible; and at the same time that the circular knife revolves vertically, the frame containing the clamps with the pieces of cork, turns horizontally, bringing the corks, one by one, up to the edge of the knife, when, to render each piece of cork cylindrical, the clamps, as above described, revolve upon their axes, independently of their carriage, by which means the whole circumference of the cork is brought under the action of the knife, the superfluous parts are uniformly pared off, and the cork finished smooth and cylindrical. The quantity entered for home consumption amounts to about 2200 tons per annum.

CORROSIVE SUBLIMATE; bichloride of mercury.

CORUNDUM. This mineral species includes sapphire, corundum stone, and emery. It consists of pure alumina colored from admixture with oxide of iron.

	Blue Sapphire, China.		Corundum, Bengal.	Emery, Naxos.
Alumina -	98·5	84·0	89·5	86·0
Lime - -	0·5	0·0	0·0	3·0
Silica - -	0·0	6·5	5·5	3·0
Oxide of iron -	1·0	7·5	1.25	4·0
	100·0 Klapr.	98·0 Chen.	98·2 Tennent.	96·0 Tennent.

The perfectly white crystals of sapphire are pure alumina.

There are two varieties of the perfect corundum; the sapphire so called, and the Oriental ruby; of which the latter has a rather less specific gravity, being 3·9 against 3·97. Their form is a slightly acute rhomboid, which possesses double refraction, and is inferior in hardness only to the diamond. The sapphire occurs also in 6-sided prisms.

COTTON DYEING. (*Teinture de Coton*, Fr.; *Baumwollenfärberei*, Germ.) Cotton and linen yarns and cloths have nearly the same affinity for dyes, and may therefore with propriety be treated, in this respect, together. After they have acquired the proper degree of whiteness (see BLEACHING), they are still unfit to receive and retain the dyes in a permanent manner. It is necessary, before dipping them into the dye-bath, to give them a tendency to condense the coloring particles within their cavities or pores, and to communicate such chemical properties as will fix these particles so that they will not separate, to whatever ordinary trial they may be subjected. All the colors which it would be desirable to transfer to these stuffs unfortunately do not possess this permanence. Men of science engaged in this important art have constantly aimed at the discovery of some new processes which may transfer into the class of fast colors those dyes which are at present more or less fugitive. Almost all the goods manufactured of cotton, flax, or hemp, are intended to be washed, and ought, therefore, to be so dyed as to resist the alkaline and soapy solutions commonly used in the laundry. Vitalis distinguished dyed cottons into three classes; 1. the *fugitive*, or fancy-colored (*petit teint*), which change their hue or are destroyed by one or two boils with soap; 2. those which resist five or six careful washings with soap, are *good* dyes, (*bon teint*); and those which were still more durable, such as Turkey reds, may be called fast colors (*grand teint*). The colors of Brazil-wood, logwood, annotto, safflower, &c., are *fugitive;* those made with madder without an oily base, are *good;* and those of madder with an oily mordant, are *fast*. It is, however, possible to point out certain processes for giving these different orders of dyes a greater degree of fixity.

I shall describe, in the five following paragraphs, the operations conducive to the fixation of colors upon cotton and linen.

1. *Galling*. Either gall-nuts alone, or sumach alone, or these two substances united, are employed to give to cotton the fast dye preparation. 2 or 3 ounces of galls for every pound of cotton, being coarsely pounded, are to be put into a copper containing about 30 gallons of water for every 100 pounds of cotton, and the bath is to be boiled till the bits

of galls feel pasty between the fingers. The fire being withdrawn, when the bath becomes moderately cool, it is passed through a hair-cloth sieve. If during this operation the liquor should become cold, it must be made once more as hot as the hand can bear. A portion of it is now transferred into another vessel, called a *back*, in which the cotton is worked till it be well penetrated with the decoction. It is then taken out, wrung at the peg or squeezed in a press, and straightway hung up in the drying-house. Some more of the fresh decoction being added to the partially exhausted liquor in the back, the process is resumed upon fresh goods.

The manipulation is the same with sumach, but the bath is somewhat differently made; because the quantity of sumach must be double that of galls, and must be merely infused in very hot water, without boiling. When galls and sumach are both prescribed, their baths should be separately made and mixed together.

2. *Aluming*. Alum is a salt which serves to prepare cotton for receiving an indefinite variety of dyes. Its bath is made as follows: For 100 pounds of scoured cotton, about 30 gallons of water, being put into the copper, are heated to about 122° F., when 4 ounces of alum, coarsely pounded, are thrown in for every pound of cotton, and instantly dissolved. Whenever the heat of the bath has fallen to about 98° F., the cotton is well worked in it, in order that the solution may thoroughly penetrate all its pores. It is then taken out, wrung at the peg or squeezed in the press, and dried in the shade. The solution of alum is of such constant employment in this kind of dyeing, that it should be made in large quantities at a time, kept in the alum tun, where it can suffer no deterioration, and drawn off by a spigot or stop-cock as wanted.

There are certain colors which require alum to be deprived of a portion of its acid excess, as a supersalt; which may be done by putting 1 ounce of crystals of soda into the tun for every pound of alum. But so much soda should never be used as to cause any permanent precipitation of alumina. When thus prepared, it is called *saturated alum*, though it is by no means neutral to litmus paper; but it crystallizes differently from ordinary alum.

Cotton does not take up at the first aluming a sufficient quantity of alum; but it must receive a second, or even a third immersion. In every case the stuff should be thoroughly dried, with an interval of one or two days between each application; and it may even be left for 10 or 12 hours moist with the alum bath before being hung in the air. When the cotton is finally dry, it must be washed before being plunged into the dye bath; otherwise, the portion of alum not intimately combined with the cotton, but adhering externally to its filaments, would come off by the heat, mix with the bath, alter the color by dissolving in it, and throw it down to the bottom of the copper, in the form of a lake, to the great loss of the dyer. Madder reds, weld yellows, and some other colors are more brilliant and faster when acetate of alumina, prepared with acetate of lead, alum, and a little potash, is used, than even saturated alum. This mordant is employed cold, and at 4° Baumé.

3. *Mordants*. See this article in its alphabetical place.

4. *Dye baths* are distinguished into two classes; the coloring bath, and the dyeing bath. The former serves to extract the coloring matters of the different substances with the exception of madder, which is always used in substance, and never as an extract, infusion, or decoction. In all these cases, when the color is extracted, that is when the dye bath is completed by the degree of heat suited to each substance, it is then allowed to cool down a certain way, and the cotton is worked or winced through it, to get the wished-for tint. This is what is called the dye bath. Several coloring baths are made in the cold; and they serve to dye also in the cold; but the greater part require a heat of 90° or 100° to facilitate the penetration of the stuffs by the coloring particles. The description of the several dye baths is given under the individual dyes.

5. *Of the washing after the dyeing.*—The washing of the cottons after they have received the dyes, is one of the most important operations in the business. If it is not carefully performed, the excess of color not combined with the fibres is apt to stain whatever it touches. This inconvenience would be of little consequence, if the friction carried off the color equally from all the points; but it does not do so, and hence the surface appears mottled. A well-planned dye house should be an oblong gallery, with a stream of water flowing along in an open conduit in the middle line, a series of dash-wheels arranged against the wall, at one side, and of dyeing coppers, furnished with self-acting winces or reels against the other. In such a gallery, the washing may be done either by hand, by the rinsing machine, or by the dash-wheel, according to the quality of the dye, and the texture of the stuffs. And they may be stripped of the water either by the jack and pin, by the squeezing roller, or by the press. Wooden pins are placed in some dye houses on each side of the wash cistern or pool. They are somewhat conical, 1½ foot high, 3½ inches in diameter at the base, 1½ at the top, are fixed firmly upright, and at a level of about 3 feet above the bottom of the cistern, so as to be handy for the workmen

See Brazil Wood, Fustic, Madder, Black Dye, Brown Dye, &c., as also Bleaching, Bran, Calico Printing, Dunging, Dyeing, &c.

Cotton may be distinguished from Linen in a cloth fabric by means of a good microscope; the former fibres being flat, riband-like and more or less contorted or shrivelled, and the latter straight, round, and with cross knots at certain distances. These two fibrous matters may be also distinguished by the action at a boiling heat of a strong caustic lye, made by dissolving fused potash in its own weight of water. By digestion in this liquor, linen yard becomes immediately yellow, while the cotton yarn remains white. The best way of operating is to immerse a square inch of the cloth to be tested for two minutes in the above boiling hot caustic lye, to lift it out on a glass rod, press it dry between folds of blotting-paper, and then to pull out a few of the warp and weft threads—when the linen ones will be found of a deep yellow tint, but the cotton, white or very pale yellow.

Cotton (*Alkalized*). The *mercurized* cotton, as it has been called, is chemically identical with the natural, but instead of having its fibres flattened and twisted, it has them cylindrical, as seen in the microscope. In fact, the moment they are touched by the alkaline lye they untwist themselves, contract in length, and retain the rounded form after the soda is removed by washing. We can thus conceive how a larger quantity of dye may be imbibed, as the substance becomes more porous. The formula of the sodaed cotton is given by Mr. Gladstone as $C_{24} H_{20} O_{20} KO$, when potash is the alkali employed.

COTTON FACTORY (*General Construction of*).—There is no textile substance whose filaments are so susceptible of being spun into fine threads of uniform twist, strength, and diameter, as cotton wool. It derives this property from the smoothness, tenacity, flexibility, elasticity, peculiar length, and spiral form of the filaments; hence, when a few of them are pulled from a heap with the fingers and thumb, they lay hold of and draw out many others. Were they much longer they could not be so readily attenuated into a fine thread, and were they much shorter the thread would be deficient in cohesion. Even the differences in the lengths of the cotton staple are of advantage in adapting them to different styles of spinning and different textures of cloth.

If we take a tuft of cotton wool in the left hand, and seizing the projecting fibres with the right, slowly draw them out, we shall perceive with what remarkable facility they glide past each other, and yet retain their mutual connexion, while they are extended and arranged in parallel lines, so as to form a little riband susceptible of considerable elongation. This demonstration of the ductility, so to speak, of cotton wool, succeeds still better upon the carded fleece in which the filaments have acquired a certain parallelism; for in this case the tiny riband in being drawn out by the fingers to a moderate length, may at the same time receive a gentle twist to preserve its cohesion till it becomes a fine thread.

Hence we may imagine the steps to be taken or the mechanical processes to be pursued in cotton spinning. After freeing the wool of the plant from all foreign substances of a lighter or a heavier nature, the next thing is to arrange the filaments in lines as parallel as possible, then to extend them into regular ribands, to elongate these ribands by many successive draughts, doubling, quadrupling, or even octupling them meanwhile, so as to give them perfect equality of size, consistence and texture, and at the same time to complete the parallelism of the fibres by undoing the natural convolutions they possess in the pod. When the rectilinear extension has been thus carried to the fineness required by the spinner, or to that compatible with the staple, a slight degree of torsion must accompany the further attenuation; which torsion may be either momentary, as in the tube roving machine, or permanent, as in the bobbin and fly frame. Finally, the now greatly attenuated soft thread, called a *fine roving*, is drawn out and twisted into finished cotton yarn, either by continuous indefinite gradations of drawing and twisting, as in the throstle, or by successive stretches and torsions of considerable lengths at a time, as in the mule.

Mechanical spinning consists in the suitable execution of these different processes by a series of different machines. After the carding operation, these are made to act simultaneously upon a multitude of ribands and spongy cords or threads by a multitude of mechanical hands and fingers. However simple and natural the above described course of manufacture may appear to be, innumerable difficulties stood for ages in the way of its accomplishment, and so formidable were they as to render their entire removal of late years in the cotton factories of England one of the greatest and most honorable achievements of human genius.

1. The *cleaning* and opening up or loosening the flocks of cotton wool, as imported in the bags, so as to separate at once the coarser and heavier impurities as well as those of a lighter and finer kind.

2. The *carding*, which is intended to disentangle every tuft or knot, to remove every remaining impurity which might have eluded the previous operation, and finally to prepare for arranging the fibres in parallel lines, by laying the cotton first in a fleecy web, and then in a riband form.

3. The *doubling* and *drawing out* of the card-ends or ribands, in order to complete the parallelism of the filaments, and to equalize their quality and texture.

4. The *roving* operation, whereby the *drawings* made in the preceding process are greatly attenuated, with no more twist than is indispensable to preserve the uniform continuity of the spongy cords; which twist either remains in them, or is taken out immediately after the attenuation.

5. The *fine roving* and *stretching* come next; the former operation being effected by the fine bobbin and fly frame, the latter by the stretcher mule.

6. The *spinning* operation finishes the extension and twist of the yarn, and is done either in a continuous manner by the water twist and throstle, or discontinuously by the mule; in the former, the yarn is progressively drawn, twisted, and wound upon the bobbins; in the latter it is drawn out and twisted in lengths of about 56 inches, which are then wound all at once upon the spindles.

7. The seventh operation is the winding, doubling, and singeing of the yarns, to fit them for the muslin, the stocking, or the bobbin net lace manufacture.

8. The *packing press*, for making up the yarn into bundles for the market, concludes this series.

9. To the above may be added the operations of the dressing machines, and,

10. The power-looms.

The site of the factory ought to be carefully selected in reference to the health of the operatives, the cheapness of provisions, the facilities of transport for the raw materials, and the convenience of a market for the manufactured articles. An abundant supply of labor, as well as fuel and water for mechanical power, ought to be primary considerations in setting down a factory. It should therefore be placed, if possible, in a populous village, near a river or canal, but in a situation free from marsh malaria, and with such a slope to the voider stream as may ensure the ready discharge of all liquid impurities. These circumstances happily conspire in the districts of Stockport, Hyde, Stayleybridge, Duckenfield, Bury, Blackburn, &c., and have eminently favored the rapid extension of the cotton manufactures for which these places are preeminent.

Mr. Orrell's Cotton Factory.—The mill consists of a main body with two lateral wings, projecting forwards, the latter being appropriated to store-rooms, a counting-house, rooms for winding the yarn on bobbins, and other miscellaneous purposes. The building has 6 floors besides the attic story. The ground-plan comprehends a plot of ground 280 feet long by 200 feet broad, exclusive of the boiler sheds.

The right-hand end, A (*fig.* 389) of the principal building, is separated from the main body by a strong wall, and serves in the three lower stories for accommodating two ninety-horse steam engines, which are supplied with steam from a range of boilers contained in a low shed exterior to the mill.

The three upper stories over the steam engine galley are used for unpacking, sorting, picking, cleaning, willowing, batting, and lapping the cotton wool. Here are the willow, the blowing, and the lap machines, in a descending order, so that the lap machine occupies the lowest of the three floors, being thus most judiciously placed on the same level with the preparation room of the building. On the fourth main floor of the factory there are, in the first place, a line of carding engines arranged, near and parallel to the windows, as shown at B, B, in the ground plan (*fig.* 389), and, in the second place, two rows of drawing frames, and two of bobbin and fly frames, in alternate lines, parallel to each other, as indicated by D, C, D, C, for the drawing frames, and E, E, E, E, for the bobbin and fly frames in the ground plan. The latter machines are close to the centre of the apartment.

The two stories next *under* the preparation room are occupied with throstle frames, distributed as shown at F, F, in the ground plan. They stand in pairs alongside of each other, whereby two may be tended by one person. These principal rooms are 280 feet long, and nearly 50 feet wide. The two stories *over* the preparation room, viz., the fifth and sixth floors from the ground, are appropriated to the mule jennies, which are placed in pairs fronting each other, so that each pair may be worked by one man. Their mode of distribution is shown at G G, in the ground-plan. The last single mule is seen standing against the end wall, with its head-stock projecting in the middle.

The ground floor of the main building, as well as the extensive shed abutted behind it, marked by N, H, H, in the plan, is devoted to the power looms, the mode of placing which is plainly seen at H, H, H.

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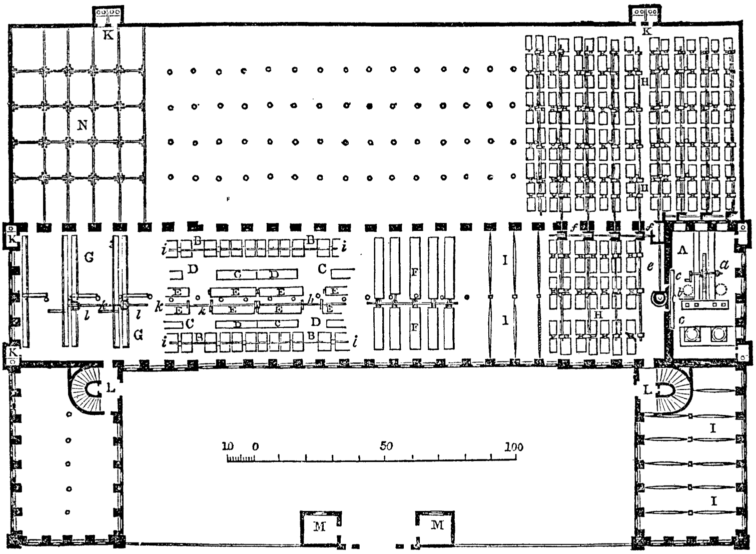
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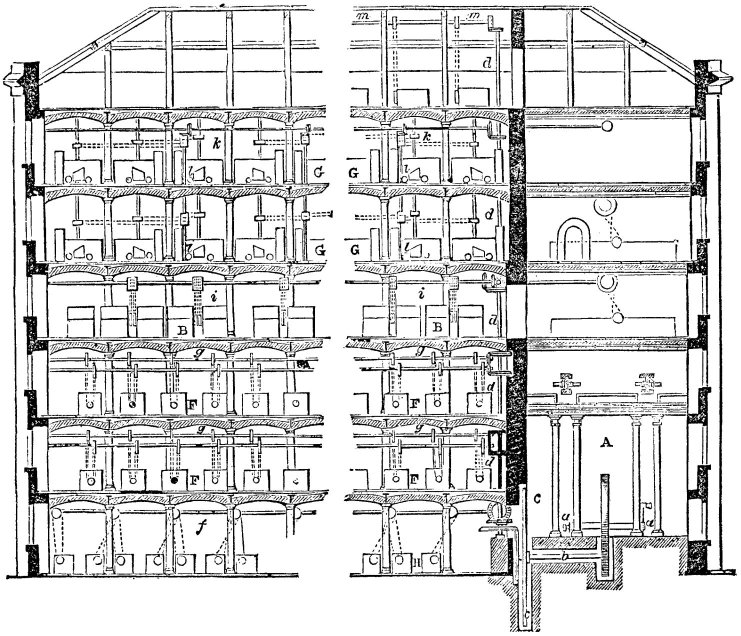
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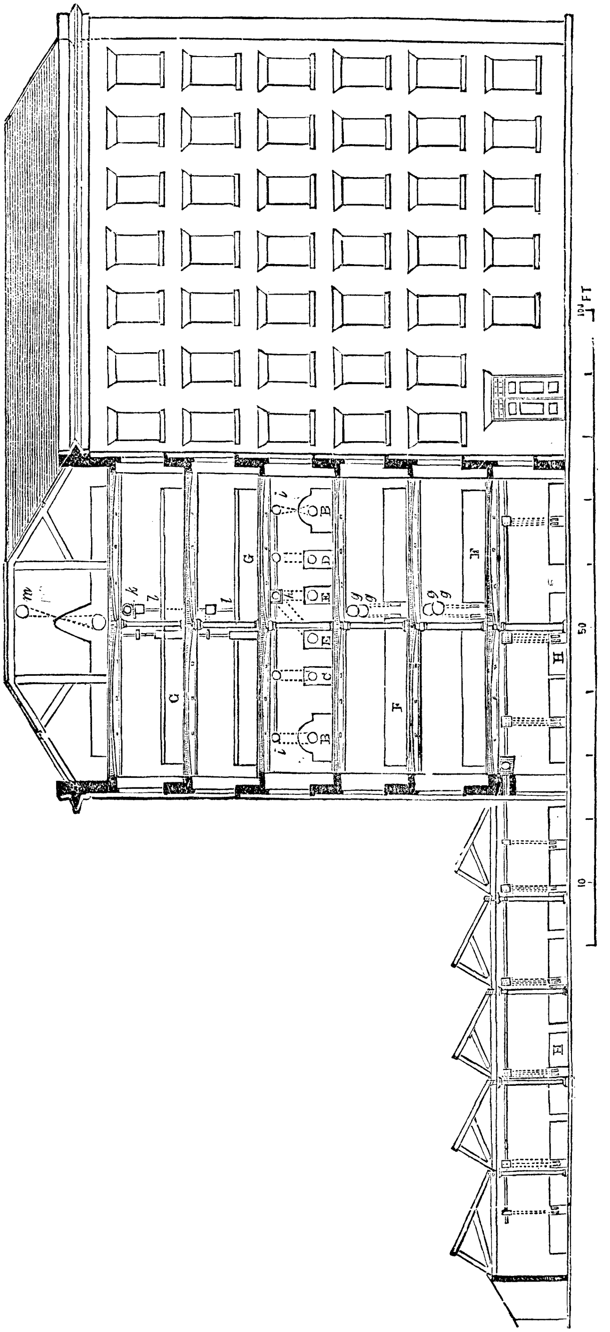

The attic story accommodates the warping mills, and the warp dressing machines subservient to power weaving.

The winding machines, and some extra mules (self-actors) are placed in the wings the five winding machines being in the two top rooms of the left wing.

We shall briefly sum up the references in the ground-plan as follows:—

A, the grand apartment for the steam engines.

B, the distribution of the carding engines, the moving shaft or axis running in a straight line through them, with its pulleys for receiving the driving bands.

C, C, the drawing frames.

D, D, the jack, or coarse bobbin and fly frames.

E, E, the fine roving or bobbin and fly frames.

F the arrangement of the throstle frames, standing in pairs athwart the gallery, in the 2d and 3d flats.

G, the mules are here represented by their roller beams, and the outlines of their head-stocks, as placed in the 5th and 6th stories.

H, the looms with their driving pulleys projecting from the ends of their main axes. Sometimes the looms are placed in parallel straight lines, with the rigger pulleys of the one alternately projected more than the other, to permit the free play of the driving-belts; sometimes the looms are placed, as generally in this engraving, alternately to the right and left, by a small space, when the pulleys may all project equally. The former plan is the one adopted in Mr. Orrell's mill.

I, represents the cast-iron girders which support the floors of this fire-proof building.

K, K, are closets placed in each floor, in the recesses of a kind of pilasters built against the outside of the edifice. These hollow shafts are joined at top by horizontal pipes, which all terminate in a chest connected with the suction axes of a fan, whereby a constant draught of air circulates up the shafts, ventilates the apartments, and prevents the reflux of offensive effluvia from the water-closets, however careless the work-people may be. The tunnels toward the one end of the building are destined for the men; to ward the other for the women.

L, L, are the staircases, of a horse-shoe form, the interior space or shaft in the middle being used for the teagle or hoist. In the posterior part of the shaft a niche or groove is left for the counter-weight to slide in, out of the way of the ascending and descending platform.

M, M, are the two porters' lodges, connected to the corner of each wing by a handsome iron balustrade. They are joined by an iron gate.

It will be observed that the back loom-shed has only one story, as shown in section, *fig.* 391). In the ground-plan of the shed, N represents the roofing, of wood-work. The rafters of the floors rest at their ends upon an iron plate, or shoe with edges (as it is called), for the girders to bear upon.

The two steam engines, of fully 90 horse power each, operate by cranks, which stand at right angles upon the shaft marked *a* both in the plan and section. In the centre, between the bearings, is a large cog-wheel, driving a smaller one upon the shaft marked *b* in both figures, to which the fly-wheel *c* belongs. That prime motion wheel is magnificent, and possesses a strength equal to a strain of 300 horses. From this shaft motion is given to the main or upright shaft *d*, in the section, by two bevel wheels, visible at the side and on the top of the great block of stone, about 5 tons weight (*fig.* 391), which gives a solid basis to the whole moving apparatus.

The velocity of the piston in these steam engines is 240 ft. per minute.

The first shaft makes 44·3 revolutions per minute; the main upright shaft 58·84 per minute. The steam engines make 16 strokes per minute; and the length of their strokes is 7 ft. 6 in.

As the one engine exerts its maximum force when the other has no force at all, and as the one increases as the other diminishes in the course of each pair of strokes, the two thus cooperate in imparting an equable impulsion to the great geering and shafts, which, being truly made, highly polished, and placed in smooth bearings of hard brass, revolve most silently and without those vibrations which so regularly recurred in the old factories, and proved so detrimental to the accurate performance of delicate spinning frames.

To the horizontal ramifications from the upright shaft any desired velocity of rotation may be given by duly proportioning the diameters of the bevelled wheels of communication between them; thus, if the wheel on the end of the horizontal shaft have one half or one third the diameter of the other, it will give it a double or a triple speed.

In the lowest floor, the second bevel wheel above the stone block drives the horizontal shaft *e*, seen in the ground plan; and thereby the horizontal shaft *f*, at right angles to the former, which runs throughout the length of the building, as the other did through its breadth, backward. The shaft *f* lies alongside of the back window wall, near the ceiling; and from it the tranverse slender shafts proceed to the right and left in the main building, and to the shed behind it, each of them serving to drive two lines of looms. These slender or branch shafts are mounted with pulleys, each of which drives four looms by four separate bands.

In the second and third floors, where the throstles are placed, the shaft *d* is seen in the section to drive the following shafts:—

Upon the main upright shaft *d* (*fig.* 390), there are in each of these stories two horizontal bevel wheels, with their faces fronting each other (shown plainly over *d d*), by which are moved two smaller vertical bevel wheels, on whose respective axes are two parallel shafts, one over each other, *g*, *g*, which traverse the whole length of the building. These two shafts move therefore with equal velocities, and in opposite directions. They run along the middle space of each apartment; and wherever they pass the rectangular line of two throstle frames (as shown at F in the ground plan) they are each provided with a pulley; while the steam pulleys on the axes of two contiguous throstles in one line are placed as far apart as the two diameters of the said shaft-pulleys. An endless strap goes from the pulley of the uppermost horizontal shaft *g*, round the steam or driving-pulley of one throstle frame; then up over the pulley of the second or lower shaft, *g*; next up over the steam pulley of a second throstle; and, lastly, up to the pulley of the top shaft, *g*. See *g g* in the throstle floors of the cross section.

In the preparation room, three horizontal shafts are led pretty close to the ceiling through the whole length of the building. The middle one, *h* (see the plan *fig.* 389), is driven immediately by bevel wheels from the main upright shaft *d* (*fig.* 390). The two sides ones, *i*, *i*, which run near the window walls, are driven by two horizontal shafts, which lead to these side shafts. The latter are mounted with pulleys, in correspondence with the steam pulleys of two lines of carding engines, as seen between the cards in the plan. The middle shaft *h*, drives the two lines of bobbin and fly frames, E, E, E, E (see cross section), and short shafts *i*, *i*, seen in the cross section of this floor, moved from the middle shaft *h*, turning in gallows fixed to the ceiling, over the drawing and jack frames, give motion to the latter two sets of machines. See C D in the cross section.

To drive the mules in the uppermost story, a horizontal shaft *k* (see longitudinal and cross sections, as well as ground plan) runs through the middle line of the building, and receives motion from bevel wheels placed on the main upright shaft, *d*, immediately beneath the ceiling of the uppermost story. From that horizontal shaft, *k*, at every second mule, a slender upright shaft, *l*, passing through both stories, is driven (see both sections). Upon these upright branch shafts are pulleys in each story, one of which serves for two mules, standing back to back against each other. To the single mules at the ends of the rooms the motions are given by still slenderer upright shafts, which stand upon the head stocks, and drive them by wheel-work, the steps (top bearings) of the shafts being fixed to brackets in the ceiling.

In the attic, a horizontal shaft, *m m*, runs lengthwise near the middle of the roof, and is driven by wheel work from the upright shaft. This shaft, *m*, gives motion to the warping mills and dressing machines.

This cotton mill having been erected according to plans devised and executed by that very eminent engineer, Mr. Fairbairn, of Manchester, may be justly reckoned a model of factory architecture. It is mounted with 1,100 power looms, of which 100 require steam power equivalent to 25 horses to impel them, inclusive of the preparation and spinning operations competent to supply the looms with yarn. A third steam engine is added.

Ten looms, with the requisite dressing, without spinning, are considered to be equivalent to 1 horse power in a steam engine. Steam power equivalent to 1 horse will drive—

500 mule spindles,
300 self-actor spindles,
180 throstle spindles of the common construction; in which estimate the requisite preparation processes are included.

In Mr. Orrell's mill there are 6,474 spindles in each of the throstle-frame floors - - -	12,948	spindles
And 14 pairs of mules in each of the 2 mule floors, containing altogether - - -	24,928	"
19 self-actors in the wing, containing - -	7,984	"
Total yarn spindles -	45,860	

One of the most compact and best-regulated modern factories, on the small scale which I visited in Lancashire, consisted of the following system of machines:—

1 willow, 1 blowing machine, 1 lap machine, capable, together, of cleaning and lapping 9,000 pounds of cotton per week, if required.
21 cards, breakers, and finishers, which carded 5,000 lbs. of cotton every week of 69 hours' work, being about 240 lbs. per card.
3 drawing-frames, of 3 heads each.
3 coarse bobbin and fly frames.
7 fine do. No stretcher mule.
12 self-actor mules, of Sharp and Roberts's construction, of 404 spindles each =4,848 mule spindles.
10 throstle frames, of 236 spindles each =2,360 spindles.
7 dressing machines.
236 power looms.
2 warping mills.
300 winding spindles for winding the warp.

The rovings have 4 hanks in the pound, and are spun into yarn No. 38 on the throstle, as well as the mule.

One bobbin of the roving (compressed) lasts 5 days on the self-actors, and 6 days on the throstles.

According to the estimate of Peile & Williams, of Manchester, 66 horses power of a steam engine are equivalent to 396 power looms, including 16 dressing machines; the cloth being 36 inches wide upon the average, and the yarn varying in fineness from 12's to 40's, the mean being 26's. Here, the spinning and preparation not being included, the allowance of power will appear to be high. The estimate given above assigns 10 looms, with the requisite dressing, to 1 horse; but the latter assigns no more than 6.

For the following experimental results, carefully made with an improved steam-engine *indicator*, upon the principle of Mr. Watt's construction, I am indebted to Mr. Bennet, an eminent engineer in Manchester. His mode of proceeding was to determine, first of all, the power exerted by the factory steam engine when all the machines of the various floors were in action; then to detach, or throw out of geer, each system of machines, and to note the diminution of force now exercised. Finally, when all the machines were disengaged, he determined the power requisite to move the engine itself, as well as the great geering-wheels and shafts of the factory.

He found at the factory of S. A. Beaver, Esq., in Manchester, that 500 calico looms (without dressing) took the power of 33 horses, which assigns 15 looms to 1 horse power.

At Messrs. Birlie's factory, in Manchester, he found that 1,080 spindles in 3 self-actor mules took 2.59 horses, being 417 spindles for 1 horse power; that 3,960 spindles in 11 self-actors took 8.33 horses, being 475 spindles per horse power; 1080 spindles in 3 self-actors took 2 horses, being 540 spindles per horse.

At Messrs. Clarke & Sons, in Manchester, that 585 looms for weaving fustians of various breadths took 54 horses power, exclusive of dressing machines, being 11 looms to 1 horse.

At J. A. Beaver's, on another occasion, he found that 1,200 spindles, of Danforth's construction, took 21 horses, being 57 spindles per horse power; and that in a second trial the power of 22 horses was required for the same effect, being 54 Danforth's spindles per horse power.

An excellent engine of Messrs. Bolton & Watt, being tried by the indicator, afforded the following results in a factory:—

A 60 horse boat-engine (made as for a steam boat) took 14½ horses power to drive the engine with the shafts - - - - -	14·5
3½ blowing machines, with their three fans - - - - -	21·55
10 dressing machines - - - - - - - - -	10·25
12 self-actor mules, of 360 spindles each (720 spindles per horse power)	6·00
6 Danforth throstle frames, containing 570 spindles (96 in each), being 93 spindles to 1 horse power - - - - - -	6·20

At Bollington, in a worsted mill, he found that 106½ spindles, including preparation, took 1 horse power upon throstles. N. B. There is no carding in the long wool or worsted manufacture for merinos:—

At Bradford, in Yorkshire, he found that a 40 horse power boat-engine, of Bolton & Watt's, drove 598 calico looms, 6 dressing machines (equivalent to dress warp for 180 of the said looms), and 1 mechanic's workshop, which took 2 horses power. Other engineers estimate 200 common throstle spindles, by themselves, to be equivalent to the power of 1 horse.

The shafts which drive the cards revolve about 120 times per minute, with a driving pulley of from 15 to 17 inches in diameter.

The shafts of the drawing, and the bobbin and fly frames, revolve from 160 to 200 times per minute, with pulleys from 18 to 24 inches in diameter.

The shafts of throstle frames in general turn at the rate of from 220 to 240 times per minute, with driving pulleys 18 inches in diameter, when they are spinning yarn of from No. 35 to 40. The shafts of mules revolve about 130 times per minute, with pulleys 16 inches in diameter.

The shafts of power looms revolve from 110 to 120 times per minute, with pulleys 15 inches in diameter.

The shafts of dressing machines revolve 60 times per minute, with pulleys 14 inches in diameter.

Before quitting the generalities of the cotton manufacture I way state the following facts communicated also by Mr. Bennet:—

A wagon-shaped boiler, well set, will evaporate 12 cubic ft. of water with 1 cwt. of coals; and a steam boiler with winding flues will evaporate 17 cubic ft. with the same weight of fuel: $7\frac{2}{10}$ lbs. of coals to the former boiler are equivalent to 1 horse power exerted for an hour, estimating that a horse can raise 33,000 lbs. 1 foot high in a minute.

The first cotton mill upon the fire-proof plan was erected, I believe, by the Messrs. Strutt, at Belper, in the year 1797; that of Messrs. Phillips & Lee, at Manchester, in 1801; that of H. Houldsworth, Esq., of Glasgow, in 1802; and that of James Kennedy, at Manchester, in 1805; since which time all good factories have been built fire-proof, like Mr. Orrell's.

The heating of the apartment of cotton factories is effected by a due distribution of cast-iron pipes, of about 7 or 8 inches diameter, which are usually suspended a little way below the ceilings, traverse the rooms in their whole length, and are filled with steam from boilers exterior to the building. It has been ascertained that one cubit foot of boiler will heat fully more than 2,000 cubic ft. of space in a cotton mill, and maintain it at the temperature of about 75° Fahr. If we reckon 25 cubit ft. contents of water in a waggoned-shaped steam boiler as equivalent to 1 horse power, such a boiler would be capable of warming 50,000 cubic ft. of space; and therefore a 10 horse steam boiler will be able to heat 500,000 cubic ft. of air from the average temperature, 50°, of our climate, up to 75°, or perhaps even 80° Fahr.

It has been also ascertained that in a well-built cotton mill, one superficial foot of exterior surface of cast-iron steam pipe will warm 200 cubic ft. of air. In common cases for heating churches and public rooms, I believe that one half of the above heating surface will be found adequate to produce a sufficiently genial temperature in the air. The temperature of the steam is supposed to be the same with that in Mr. Watt's low-pressure engines, only a few degrees above 212°—the boiling point of water.

The pipes must be freely slung, and left at liberty to expand and contract under the changes of temperature, having one end at least connected with a flexible pipe of copper or wrought iron, of a swan-neck shape. Through this pipe the water of condensation is allowed to run off. The pipes should not be laid in a horizontal direction, but have a sufficient slope to discharge the water. The pipes are cast from half an inch to three quarters thick in the metal. In practice the expansion of steam pipes of cast-iron may be taken at about one tenth of an inch in a length of 10 feet, when they are heated from a little above the freezing to the boiling point of water. The upper surface of a horizontal steam pipe is apt to become hotter than the bottom, if the water be allowed to stagnate in it; the difference being occasionally so great, as to cause a pipe 60 feet long to be bent up 2 inches in the middle.

In arranging the steam pipes provision ought to be made not only for the discharge of the water of condensation, as above stated, but for the ready escape of the air; otherwise the steam will not enter freely. Even after the pipes are filled with steam, a little of it should be allowed to escape at some extreme orifice, to prevent the re-accumulation of air discharged from the water of the steam boiler. In consequence of water being left in the pipes serious accidents may happen; for the next time the steam is admitted into them, the regularity of heating and expansion is impeded, some part of the pipe may crack, or a violent explosion may take place, and the joints may be racked to a very considerable distance, every way, from the place of rupture, by the alternate expansions and condensations. The pipes should therefore be laid, so as to have the least possible declivity, in the direction of the motion of the steam.

Formerly, when drying rooms in calico printing works were heated by iron stoves, or cockles, their inmates were very unhealthy, and became emaciated; since they have been heated by steam pipes the health of the people has become remarkably good, and their appearance frequently blooming.

COTTON MANUFACTURE. (*Filature de Coton*, Fr.; *Baumwollenspinnerie*,

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Germ.) Cotton is a filamentous down, which invests the seeds of the plant called *gossypium* by Linnæus, and placed by him in the class *monadelphia*, and order *monandria*, but belonging to the natural family of *malvaceæ*. It has a cup-shaped calyx, obtusely five-toothed, enclosed in a three-cleft exterior calyx; the leaflets are united at their base, of a heart shape, and toothed; stigmas three to five; capsule three to five celled and many seeded; seeds bearing a downy wool. Thirteen species are described by Decandolle, but their characters are very uncertain, and no botanist can assign to a definite species of the plant, the very dissimilar staples of the cotton filaments found in commerce. The leaves are generally palmate and hairy; and the blossoms are large, and of a beautiful yellow. The *gossypium religiosum* of Tranquebar has white blossoms in some of its varieties, to which probably the white cotton of Rome, cultivated in the Jardin des Plantes at Paris, belongs. The filaments differ in length, flexibility, tenacity, and thickness, in different cottons, whence the great differences of their value to the cotton-spinner, as the prices current in the market show. Thus, at Liverpool, on the 1st of December, 1835, the following values were assigned to the following cottons:—

	s.	*d.*		*s.*	*d.*
Sea-island - - -	1	6	to	2	6
Demarara and Berbice - -	0	9		1	0
Pernambuco - - - - -	0	10¾		1	1½
Egyptian - - - - -	0	11½		1	2½
New Orleans - - -	0	7⅛		1	0
Bahia - - - - - -	0	8¼		0	10
Upland Georgia - - - - -	0	7⅛		0	11½
West Indian - - - - -	0	7¾		0	9
Surat - - - - - -	0	6⅛		0	8
Madras - - - - - -	0	6½		0	8
Bengal - - - - - -	0	5¼		0	6½

But it is to be observed, that there are varieties of the Sea-island Georgian cotton, so highly prized by the spinner of fine yarn, as to fetch 3*s.*, 4*s.*, or even 5*s.* per pound.

The filaments of cotton, when examined with a good microscope, are seen to be more or less riband-like, and twisted; having a breadth varying from $\frac{1}{800}$ of an inch in the strongest Smyrna or candle-wick cotton of the Levant, to $\frac{1}{2500}$ of an inch in the finest Sea-island.

The main distinction between cottons in the pod, is that of the black seeded and the green seeded; for the former part with their downy wool very readily to a pair of simple rollers, made to revolve nearly in contact, by the power of the human arm; while the latter retain the wool with much force, and require to be ginned, as the operation is called, by a powerful revolving circular saw-mechanism, usually driven by horse or water power. After the cotton wool is thus separated from the seeds, it is packed in large canvass bags, commonly with the aid of a screw or hydraulic press, into a very dense bale, for the convenience of transport. Each of the American bags contains about 340 lbs. of cotton wool. When this cotton is delivered to the manufacturer, it is so foul and flocky, that he must clean and disentangle it with the utmost care before he can subject it to the carding operation.

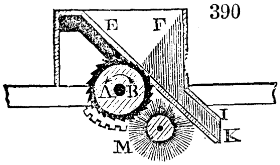

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Fig. 390, A B, is a roller, about 9 inches in diameter, which revolves in the direction of the arrow. This cylinder consists of a parallel series of oblique pointed circular saws made fast to one axis, and parted from each other by wooden rings nearly one inch and a half in thickness. Above the cylinder, is a kind of hopper E F, into which the ginner throws the seed cotton, which falls upon a grating, up through which small segments of the saw-teeth project, so as to lay hold of the fibres in their revolution, and pull them through, while the seeds, being thus separated, roll down the slope of the grid, to be discharged from the spout I K. M is a cylindrical brush placed below the grating, which revolves against the saw-teeth, so as to clear them of the adhering cotton filaments.

The *willow*, which was originally a cylindrical willow basket, whence its name, but is now a box made of wood, with revolving iron spikes, is the first apparatus to which cotton wool is exposed, after it has been opened up, picked, and sorted by hand or a rake, in what is called a *bing*. The willow exercises a winnowing action, loosens the large flocks, and shakes out much of the dirt contained in them. The frame of the willow is about 2 feet wide, and turns with its spikes at the rapid rate of 600 revolutions per minute, whereby it tosses the cotton about with great violence. The heavy impurities fall down through the grid bottom. It is exposed, however, for only a few minutes to the action of this machine. For factories, which work up chiefly the coarser and fouler cottons of India, and Upland Georgia, the conical self-acting willow, as

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constructed by Mr. Lillie at Manchester, is much employed. In it, the cotton is put in at the narrow end of the truncated cone, which, being spiked, and revolving rapidly within a nearly concentric case upon a horizontal axis, wafts it on towards the wide end, while its impurities are partly shaken out through the grid or perforated bottom, and partly sucked up through revolving squirrel wire cages, by the centrifugal action of a fan This is a powerful automatic engine, deserving the study of the curious, and is as safe as it is powerful. The cone of this huge machine makes from 400 to 600 turns per minute, and will clean 7200 pounds, or 24 bags, in a day.

After shaking out the grosser impurities by the willow, the cotton spinner proceeds to separate each individual filament of cotton wool from its fellow, so as to prepare it for carding, and to free it from every particle of foreign matter, whether lighter or heavier than itself. This second operation is performed by what are called batting (*beating*), scutching, and blowing machines, which are all now much the same, whatever difference of signification the name may have. Indeed, each machine not only beats, scutches, but blows. *Fig.* 391 exhibits a longitudinal section of a good blowing engine of modern construction. The machine is about 18 or 19 feet long, and three feet across within the case. The whole frame is made of cast-iron, lined with boards, forming a close box, which has merely openings for introducing the raw cotton wool, for taking out the cleansed wool, and removing the dust as it collects at the bottom. These doors are shut during the operation of the machine, but may be opened at pleasure, to allow the interior to be inspected and repaired.

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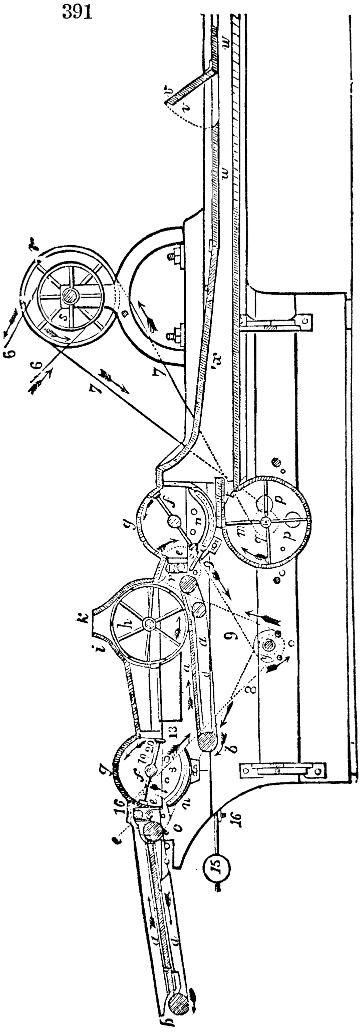

The introduction of the cotton is effected by means of an endless cloth or double apron, which moves in the direction of the arrow *a a*, at the left end of the figure, by passing round the continually revolving rollers at *b* and *c*. The two rollers at *c*, being the ones which immediately introduce the cotton into the jaws, as it were, of the machine, are called the feed rollers. The batting arm, or revolving diameter, *f e*, turns in the direction of the arrow, and strikes the flocks violently as they enter, so as to throw down any heavy particles upon the iron grating or grid at *n*, while the light cotton filaments are wafted onwards with the wind, from the rotation of the scutcher in the direction of arrow *a′*, along the second travelling apron, upon which the squirrel cage cylinder presses, and applies the cotton in the form of a lap. Above the cylindric cage *h*, which turns in the direction of its arrow, there is a pipe *k*, the continuation of the case *i*. This pipe, though broken off in the figure, communicates by a branch pipe with an air-sucking fan ventilator, not seen in this figure, but explained under Foundry. The cage *h*, by its rotation, presses down, as we have said, the half-cleaned cotton upon the cloth *a′*, which carries it forward to the second scutcher *f′*, by the second set of feed rollers *e′*. The second scutcher throws down the heavy dust upon the second grid *n′*, through which it falls upon the bottom of the case. The first scutcher makes about 1280 strokes of each of its two arms in a minute; the second 1300. The feed rollers for each are fluted. The feed cloth is either sustained by a board, or is made of parallel spars of wood, to secure it against bagging, which would render the delivery of the cotton irregular. The feed rollers make 8 turns in the minute; and as their diameter is 1½ inches, they will introduce 8 times their circumference, or 37·7 inches of the cotton spread upon the apron in that time. Upon every 12th part of an inch of the cotton, therefore, nearly 3 blows of the scutcher arm will be applied. The second feed rollers move relatively with more slowness, so that for every 2·4 blows of the scutcher, only one twelfth of an inch of cotton wool is presented.

The fan is enclosed in a cylindrical case. The wings or vanes revolve from 120 to 150 times in the minute; and while they throw the air out with nearly this velocity at their eccentric outlet in the circumference, they cause it to enter, with equal velocity, at the centre. With this centre the squirrel cage is connected by a pipe, as above stated. The sound filaments of the cotton are arrested by the sieve surface of the cylindric cage, and nothing but the broken fragments and the light dust can pass through.

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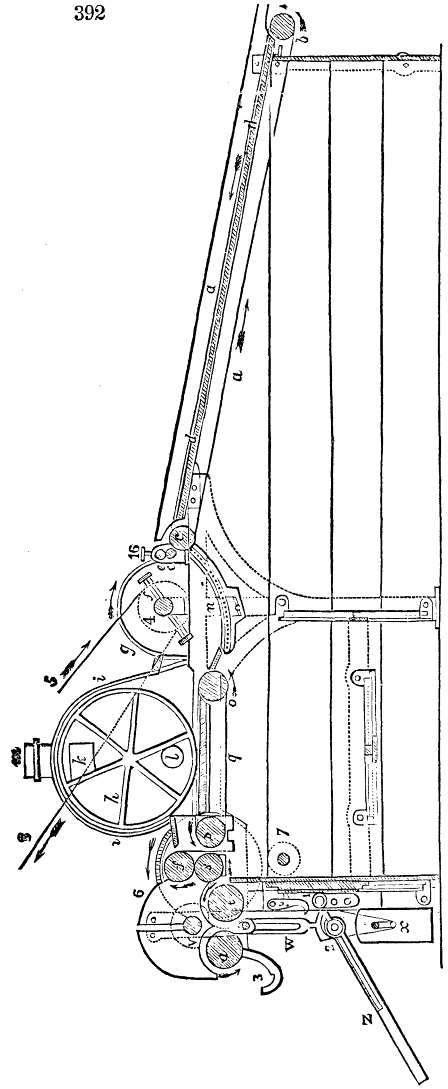

The cotton wool in the blowing machine is wafted by the second scutcher into the space *x*, *w*, *w*, provided with a fine grid bottom; or it is sometimes wound up there by rollers into a lap.

In *fig*. 391 an additional ventilator is introduced beneath at *m*, *o*, *o*, to aid the action of the scutchers in blowing the cotton onwards into the oblong trough *a*. The outlet of that fan is at *t;* and it draws in the air at its axis *q*. *u* and *v* are two doors or lids for removing the cleaned cotton wool. This last fan is suppressed in many blowing machines, as the scutching arms supply a sufficient stream of air. The dotted lines show how the motion is transmitted from the first mover at *s*, to the various parts of the machine. 6′ 6′ represent the bands leading to the main shafting of the mill. A machine of this kind can clean fully 600 pounds of short-stapled cotton wool in a day, with the superintendence of one operative, usually a young woman, to distribute the cotton upon the first feed cloth.

The second Blowing machine is usually called a *lap* machine, because, after blowing and scutching the cotton, as above described, it eventually coils the fleece upon a wooden roller at the delivering end of the apparatus. It is sometimes, also, called a *spreading machine*. A section of it is shown in *fig*. 392. The breadth of this machine is about 3 feet, as the lap formed is prepared for the usual breadth of the breaker cards, namely, 3 feet. Where the cards are only 18 inches broad, the lap machine is also made of the same breadth. In the figure we see the feed-cloth, the scutching barrel, the squirrel suction, and spreading cage, and the rollers for coiling up the lap. The lever shown below is for removing the pressure weight from the axis of the lap rollers, when a full one is to be removed, and replaced by an empty one. *m*, at the top, is the commencement of the pipe which leads to the suction fan, or ventilator. The thickness of the lap in this machine must be nicely regulated, as it determines, in a great measure, the grist of the card-ends, and even the rovings. In 12 hours such a lap machine will prepare 650 pounds of cotton.

Fig. 393 is the first scutching machine, now never seen except in the oldest factories. A B is the feed cloth; G H and M N are the two scutcher frames.

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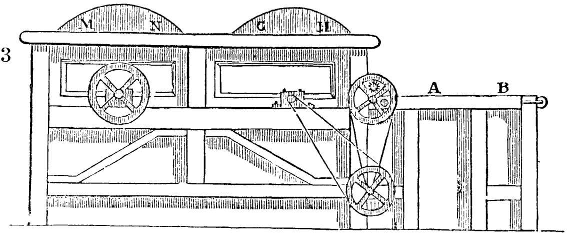

Carding is the next operation in a cotton factory. Cards are destined to disentangle the individual filaments from each other, and to lay them lengthwise, instead of being doubled up and convoluted, as they usually are in leaving the blowing and lap machines. Carding consists in the mutual action of two opposite surfaces, which are studded thick with oblique angled hooks. The wires of which these hooks are made must be very hard drawn in order to render them stiff and elastic. The middle part of the figures shows one of the staples or double teeth, the structure of which has been partly explained under Card. Suppose *a*, *fig.* 394, to be a piece of a card fillet, and *b* to be another piece, each being made fast with pins to a board; the teeth of these two cards are set in opposite directions, but are very near together, and parallel. Now suppose a flock or tuft of cotton placed between two such bristling surfaces. Let *a* be moved in the direction of its arrow, and let *b* be moved in the opposite direction, or even let it remain at rest. Every filament of the cotton will be laid hold of by each set of teeth, when their surfaces are thus drawn over each other; the teeth of *a* will pull them in a forward direction, while those of *b* will tend to retain them, or to pull them backwards. The loops or doublings will, by both movements, be opened or drawn out, so that the flocks will be converted into rows of parallel filaments, lying alongside or before each other. Each tooth will secure to itself one or more of them, and by the friction of its sides, as well as the hooks of its points, will draw them to their utmost elongation. Though one stroke of the opposite cards be inadequate to produce this equable arrangement, yet many repeated strokes must infallibly accomplish the end in view, of laying the fibres parallel.

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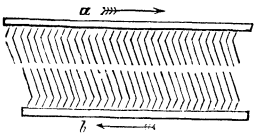

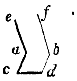

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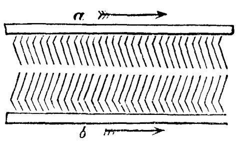

Let us suppose this end effected, and that all the fibres have been transferred to the card *a*, a transverse stroke of *b* will draw over to it a certain number of them, and indeed at each stroke there will be a new partition between the two cards, with increased parallelism, but still each card will retain a great deal of the cotton. To make one card strip another, the teeth of one of them must be placed in a reverse position, as shown in *fig.* 395.

If *a* be now drawn in the direction of its arrow along the face of *b*, it will inevitably comb out all, or almost all, the filaments from it, since the hooks of *b* have, in this position, no power of retaining them. Even the doubled fibres or loops will slip over the sloping point of *b*, in obedience to the traction of *a*. By considering these two relative positions of the cards, which take place in hand cards, simply by reversing one of them any person will be able to understand the play of a cylinder card against its flat top, or against another cylinder card, the respective teeth being in what we may call the teasing position of *fig.* 394; and also the play of a cylinder card against the doffer cylinder, in what may be called the stripping position of *fig.* 395.

Cylinder cards, so essential to the continuity and despatch of cotton factory labor, were the ingenious invention of Lewis Paul of Northampton, but were greatly improved and brought into nearly their present operative state by Sir Richard Arkwright. A carding engine consists of one or more cylinders, covered with card-leather (sometimes called card cloth), and a set of plane surfaces similarly covered, made to work against each other, but so that their points do not come into absolute contact. Some cards consist entirely of cylinders, the central main cylinder being surrounded by a series of smaller ones called urchins or squirrels. These are used solely for preparing the coarser stapled cotton, and sheep's wool for the wool spinner.

Fig. 396 represents a card of excellent construction, which may be called a *breaker* and *finisher*, as it is capable of working up the fleece roll of the lapping machine directly into a card-end or riband fit for the drawing machine. In fine spinning mills there are always, however, two cards; one coarser, called a breaker, which turns off the cotton in a broad fleece of extreme thinness, which is lapped round a cylinder; and constitutes the material presented to the finisher card, which has teeth of a finer construction.

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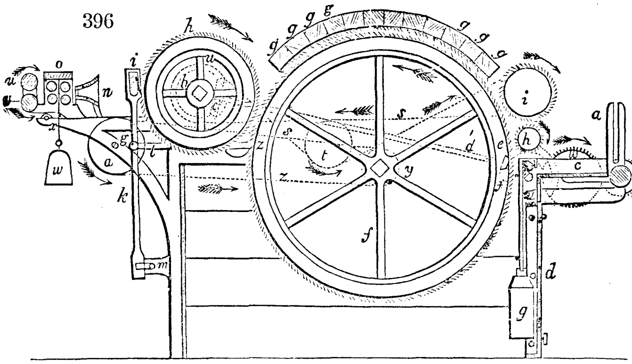
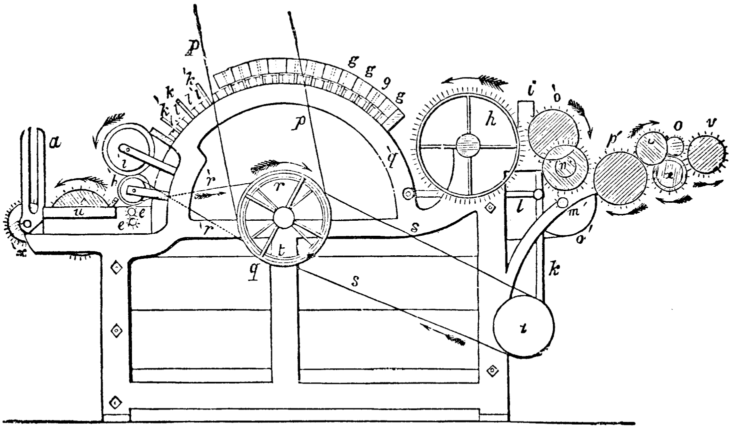


a is one of the two upright slots, which are fixed at each side of the engine for receiving the iron gudgeons of the wooden cylinders round which the fleece of the lapping machine is rolled. The circumference of this coil rests upon a roller *b*, which is made to turn slowly in such a direction as to aid the unfolding of the lap by the fluted cylinders *e*. The lap proceeds along the table seen beneath the letter *c*, in its progress to the fluted rollers, which are an inch and one sixth in diameter, and have 28 flutings in their circumference. *g* is a weight which hangs upon the axis of the upper roller, and causes it to press upon the under one: *f* is the main card drum; *g g g*, the arch formed by the flat top cards; *h*, the small card cylinder for stripping off the cotton, and therefore called the doffer, as we have said; *i*, the doffer-knife or comb for stripping the fleecy web from the doffer; *k l q m*, the lever mechanism for moving these parts. At *d* there is a door for permitting the tenter to have access to the interior of the engine, and to remove whatever dirt, &c. may happen to fall into it. In *fig.* 397 we see the manner of fixing the flat tops *g g* over the drum; and for making the matter clearer, three of the tops are removed. Upon the arched cast-iron side of the frame, a row of strong iron pins *k* are made fast in the middle line; and each top piece has, at each of its ends, a hole, which fits down upon two such opposite pins. *l l* are screws whose heads serve as supports to the tops, by coming into contact with the bottom of the holes, which are not of course bored through the wood of the tops. By turning the heads of these screws a little the one way or the other, the pins may be lengthened or shortened in any degree, so as to set the tops very truly in adjustment with the drum teeth revolving beneath them. *h′* is the small runner or urchin, and *i′* the large runner; both of which are spirally covered from end to end with narrow card fillets in the same manner as the doffer. The main drum is on the contrary covered with card cloth, in strips laid on parallel to its axis, with interjacent parallel smooth leather borders. The teeth of these several cards are set as represented in the figure, and their cylinders revolve as the arrows indicate. The runners as well as the doffer cylinder may be set nearer to or farther from the drum *f*; but the screws intended for this adjustment are omitted in the drawings, to avoid confusion of the lines.

The card-end or fleece taken off the doffer *h* by the crank and comb mechanism *i k m*, passes through the tin plate or brass funnel *n*, *fig* 396, whereby it is hemmed in and contracted into a riband, which is then passed through between a pair of drawing rollers *o*. It is next received by the rollers *u v*, which carry it off with equable velocity, and let it fall into the tin cans placed below, or conduct it over a friction pulley, to be wound along with many other card-ends upon a lap roller or large bobbin. The latter mechanism is not shown in this figure. A sloping curved tin or brass plate, channelled or ridged along its surface, conducts the card ribands separately; there are two smooth iron rollers for condensing the several ribands, and a wooden pin round which the ribands are lapped, resting between two leather-covered rollers, one of which receives motion



from mill gearing, and imparts it by friction to the lap roller over it. The iron ends of the lap roller lie in upright slots, which allow them freedom to rise as the roller gets filled with fleece.

The two pairs of rollers at *o* effect the extension of the card-end, and reduce its size. The under rollers are made of iron and fluted; the upper ones are also made of iron, but they are covered with a coat of leather, nicely glued on over a coat of flannel, which two coats render them both smooth and elastic. Two weights, *w*, press the upper cylinders steadily down upon the under ones. Between the first and second pair there is a certain interval, which should be proportioned to the length of the cotton staple. The second, or that furthest from the funnel, revolves with greater velocity than the first, and therefore turns out a greater length of riband than it receives from its fellow; the consequence is a corresponding extension of the riband in the interval between the two pairs of rollers.

The motions of the several parts of the engine are effected in the following way. The band, *p p*, *fig.* 397, which comes down from the pulley upon the main shaft near the ceiling of the work-room, drives, by means of the pulley *q*, the drum *f*, *fig.* 396, with a velocity of from 120 to 140 revolutions in a minute. From another pulley *r*, on the axis of the drum, the axis of *t* is driven by the band *s* working round the pulley *t* on its end. This shaft drives the crank and lever mechanism of the stripper knife *i*. A third pulley of the same size as *r* is fixed just within the frame to the other end of the drum, and from it a crossed or close band *r′* goes to a pulley upon the small runner *h′*, to give this its rapid rotation. Upon the opposite end of the engine in *fig.* 396, these wheels and pulleys are marked with dotted lines. Here we may observe, first, a pulley *y* upon the drum, and a pulley *a′*, which receives motion from it by means of the band *z*. The axis of *a′* carries in front a pinion *m′*, which sets in motion the wheel *n′*. The latter imparts motion, by means of a pinion and intermediate wheel *o′*, to the wheel *h* on the doffer cylinder, and consequently to that cylinder on the one hand; and it turns, by the carrier wheel *p′*, a wheel *x*, whose axis is marked also with *x* in *fig.* 396, upon the other hand. The axis of *x′*, *fig.* 396, carries, towards the middle of the engine, a very broad wheel, which is represented by a small dotted circle. The toothed wheel *v* of the smooth roller *v′*, *fig.* 396, and the two toothed wheels *o o*, *fig.* 396, of the under rollers *o o*, *fig.* 396, work into that broad wheel. The wheel of the second or delivery fluted roller is seen to be smaller than that of the first, by which means the difference of their velocities is obtained. The large runner *i* is driven from the main drum pulley, by means of the band *s′*, and the pulley *u′*, *fig.* 396. The said band is crossed twice, and is kept in tension by the pulley *t′*, round which it passes. The motion of the fluted rollers *e*, which feed in the cotton fleece, is effected by means of a bevel wheel *b′* on the end of the doffer, which works into a similar wheel *c′* on the oblique axis *d′* (dotted lines across the drum), of the pinion *e′* upon the lower end of the same axis which turns the wheel *f′*, upon the under feed roller.

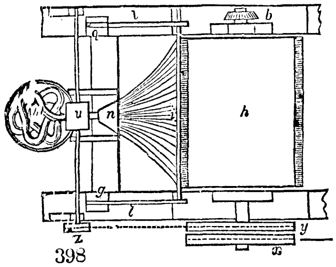
Each of the feed rollers, *fig.* 397, bears a pinion *e e* at one end, so that the upper roller turns round with the under one. The roller *b*, *fig.* 396, is set in motion by means of its wheel *x'*; which is driven by a wheel *v'* on the other end of the under feed roller, through the intervention of the large carrier wheel *w'*. The original or first motion of *b* must be as quick as that of the fluted feed rollers *e*, in order that the former may uncoil as much lap as the latter can pass on.

The annexed table exhibits the proper velocities of the different cylinders and rollers of the carding engine, which, however, are not invariable, but may be modified according to circumstances, by changing the pinions *e'*, *fig.* 396, and *w'*, according to the quality or length of the cotton staple. The velocities stated in the table will be obtained when the pulley *a'*, *fig.* 396, is made greater than *y* in the proportion of 3 to 2, and the wheels and pinions have the following number of teeth: *m'*, 18; *n'*, 50; its pinion, 18; *h*, 128; *x*, 24; the broad wheel upon the shaft of *x*, 37 teeth; the wheel *o* of the first fluted roller, 35; that of the second, 21; *v*, 44; *b'* and *e'*, 54; *e'*, 10; *f'*, 63.

Names of the parts.	Diameter in inches.	Circumference in inches.	Revolutions in one minute.	Velocity.
Drum *f* - - - - - -	35	109·9	130	142·87
Doffer *h* - - - - -	14	43·96	4·38	192·5
Runner or urchin *i'* - - - -	6·25	19·62	5·	98·1
Ditto *h'* - - - - -	3·5	11·	470·	5170·
Fluted feed roller *e* - - - -	1·167	3·664	0·696	2·55
First drawing roller *o* - - -	1·	3·14	68·71	215·75
Second ditto - - - - -	1·167	3·664	114·52	419·6
Smooth delivery roller *v* -	2·5	7·85	54·66	429·08

The operation of the runners, *h'* and *i'*, becomes very plain on comparing their speed with one another and with that of the main-drum, and taking into account the direction of the card teeth. The cotton wool, taken off from the feed-rollers by the drum, is caught by the opposite teeth of the large runner *i'*, which, on account of its slower surface rotation (98 inches per minute), may be considered to be at rest with reference to the drum, and therefore, by holding the cotton in its teeth, will commence its carding. The small runner *h'*, in consequence of its greater surface velocity (5170 inches per minute), will comb the cotton-wool back out of the teeth of the large runner, but it will give it up in its turn to the swifter teeth of the drum, which, in carrying it forwards, encounters the teeth of the top cards, and delivers up the filaments to their keeping for some time. We thus see how essential the runners are to the perfection as well as to the acceleration of the carding process for ordinary cotton wool, though for the slenderer and longer filaments of the sea-island kind they are not so well adapted. In cleaning the carding-engines the little runner must be looked to every time that the drum is examined. The large runner and the doffer require to be cleaned together. The quantity of cotton spread upon the feed-cloth, the velocity of it, and of the drawing-rollers, must all be carefully adjusted to the grist of the yarn intended to be spun.

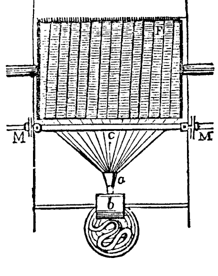
Suppose the sizes and velocities to be as represented in the preceding table, that the engine is a double card 36 inches broad, and that it is furnished with a lap from the lap-machine of which 30 feet in length weigh 5 lbs. In one minute the surface of the feed-rollers, *e*, passes 2·55 inches of that lap onwards; in the same time the main-drum will work it off. To card the whole 30 feet, therefore, 141 minutes, or 2 hours and 21 minutes will be required. In this time the circumference of the rollers, *u v*, moves through a space of 141 × 42,908 in. = 5042 ft., and delivers a card-end of that length, weighing 5 lbs., *minus* 6 per cent. for waste, that is, 4 lbs. 11½ oz. One pound will form a riband 1072 feet long, being, according to the English mode of counting, about number ⅓, or 0·357. The extension of the cotton-fleece to this degree proceeds as follows:—In the 141 minutes which the feed-rollers take to introduce the 30 feet of lap, the doffer, *h*, makes 617·58 revolutions, and the comb, or doffer knife, *i*, detaches from the doffer teeth a thin fleecy web of 2262 feet in length. The first drawing pair of fluted rollers, by its quick motion, with the aid of the funnel, *m*, converts this fleece into a riband 2535 feet long. The second pair of the fluted rollers extends this riband to 4390 feet, since their surface velocity is greater than the first pair in that proportion. The slight elongation (of only 112 feet, or about $\frac{1}{44}$) which takes place between the delivery fluted rollers and the smooth cylinders, *v*, *u*, serves merely to keep the card-end steadily upon the stretch without folding. *Fig.* 398 is a plan of the card and the fleece, where *h* is the cylinder, *n* is the funnel, *u* the pressing rollers, and *h'* the card-ends in the can.



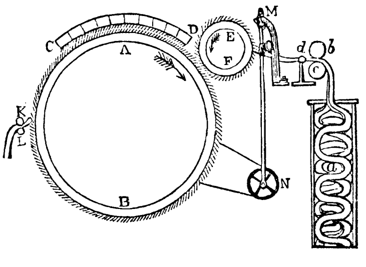
398

Figs. 399, 400, represent skeletons of the old cards to facilitate the comprehension of these complex machines. *Fig.* 399 is a plan; F is the main drum; M M is the doffer

399



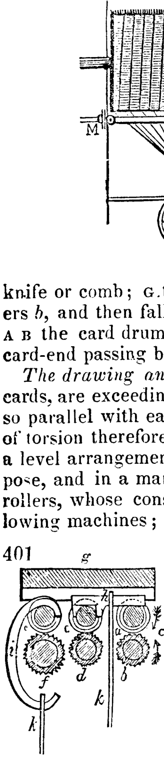
400



knife or comb; G the carded fleece hemmed in by the funnel *a*, pressed between the rollers *b*, and then falling in narrow fillets into its can. *Fig.* 400, K L are the feed rollers; A B the card drum; C D the tops; E F the doffer card; M N the doffer knife; *d*, *b*, *c*, the card-end passing between compressing rollers into the can *a*.

The drawing and doubling are the next operation. The ends, as they come from the cards, are exceedingly tender and loose, but the filaments of the cotton are not as yet laid so parallel with each other as they need to be for machine spinning. Before any degree of torsion therefore be communicated, a previous process is required to give the filaments a level arrangement in the ribands. The drawing out and doubling accomplish this purpose, and in a manner equally simple and certain. The means employed are drawing-rollers, whose construction must here be fully explained, as it is employed in all the following machines; one example of their use occurred, indeed, in treating of the cards.

401

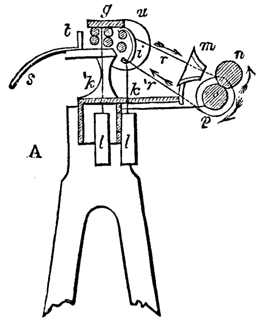


Let *a* and *b*, *fig.* 401, represent the section of two rollers lying over each other, which touch with a regulated pressure, and turn in contact upon their axes, in the direction shown by the arrows. These rollers will lay hold of the fleecy riband presented to them at *a*, draw it through between them, and deliver it quite unchanged. The length of the piece passed through in a given time will be equal to the space which a point upon the circumference of the roller would have percured in the same time; that is, equal to the periphery of one of the rollers multiplied by the number of its entire revolutions. The same thing holds with regard to the transmission of the riband through between a second pair of rollers, *c*, *d*, and a third, *e*, *f*. Thus the said riband issues from the third pair exactly the same as it entered at *a*, provided the surface speed of all the rollers be the same. But if the surface speed of *c* and *d* be greater than that of *a* and *b*, then the first-named pair will deliver a greater length of riband than the last receives and transmits to it. The consequence can be nothing else in these circumstances than a regulated drawing or elongation of the riband in the interval betwixt *a*, *b*, and *c*, *d*, and a condensation of the filaments as they glide over each other, to assume a straight parallel direction. In like manner the drawing may be repeated by giving the rollers, *e*, *f*, a greater surface speed than that of the rollers, *c* and *d*. This increase of velocity may be produced, either by enlarging the diameter, or by increasing the number of turns in the same time, or finally by both methods conjoined. In general the drawing-machine is so adjusted, that the chief elongation takes place between the second and third pair of rollers, while that between the first and second is but slight and preparatory. It is obvious, besides, that the speed of the middle pair of rollers can have no influence upon the amount of the extension, provided the speed of the first and third pair remains unchanged. The rollers, *a*, *b*, and *c*, *d*, maintain towards each other continually the same position, but they may be removed with their frame-work, more or less, from the third pair, *e*, *f*, according as the length of the cotton staple may require. The distance of the middle point from *b* and *d*, or its line of contact with the upper roller, is, once for all, so calculated, that it shall exceed the length of the cotton filaments, and thereby that these filaments are never in danger of being torn asunder by the second pair pulling them while the first holds them fast. Between *d* and *f*, where the greatest extension takes place, the distance must be as small as it can be without risk of tearing them in that way; for thus will the uniformity of the drawing be promoted. If the distance between *d* and *f* be very great, a riband passing through will become thinner, or perhaps break in the middle; whence we see that the drawing is more equable, the shorter is the portion submitted to extension at a time, and the nearer the rollers are to each other, supposing them always distant enough not to tear the staple.

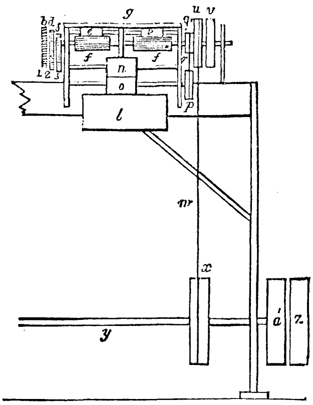
The under rollers, *b d f*, are made of iron, and, to enable them to lay firmer hold of the filaments, their surfaces are fluted with triangular channels parallel to their axes. The upper rollers, *a c e*, are also made of iron, but they are smooth, and covered with a double coating, which gives them a certain degree of softness and elasticity. A coat of flannel is first applied by sewing or glueing the ends, and then a coat of leather in the same way. The junction edges of the leather are cut slanting, so that when joined by the glue (made of isinglass dissolved in ale) the surface of the roller may be smoothly cylindrical. The top rollers are sometimes called the *pressers*, because they press by means of weights upon the under ones. These weights are suspended to the slight rods *k k'*; of which the former cperates on the roller *e* alone, the latter on the two rollers *a* and *e* together. For this purpose the former is hung to a c shaped curve *i*, whose upper hook embraces the roller *e*; the latter to a brass saddle *h*, which rests upon *a* and *c*. A bar of hard wood, *g*, whose under surface is covered with flannel, rests, with merely its own weight, upon the top rollers, and strips off all the loose hanging filaments. Similar bars with the same view are made to bear up under the fluted rollers *b d f*, and press against them by a weight acting through a cord passing over a pulley. Instead of the upper dust-covers, light wooden rollers covered with flannel are occasionally applied.

Were the drawing of a riband continued till all its fibres acquired the desired degree of parallelism, it would be apt, from excessive attenuation, to tear across, and thereby to defeat the purpose of the spinner. This dilemma is got rid of in a very simple way, namely, by laying several ribands together at every repetition of the process, and incorporating them by the pressure of the rollers. This practice is called *doubling*. It is an exact imitation of what takes place when we draw a tuft of cotton wool between our fingers and thumb in order to ascertain the length of the staple, and replace the drawn filaments over each other, and thus draw them forth again and again, till they are all parallel and of nearly equal length. The doubling has another advantage, that of causing the inequalities of thickness in the ribands to disappear, by applying their thicker to their thinner portions, and thereby producing uniformity of substance.

402



403



The drawing frame, as shown in section in *figs.* 401, 403, and in a back view in *fig.* 402, will require, after the above details, little further explanation. *l l* are the weights which press down the top rollers upon the under ones, by means of the rods *k k'* and hook *i*. Each fluted roller is, as shown at *f*, *fig.* 402, provided in the middle of its length with a thinner smooth part called the *neck*, whereby it is really divided into two fluted portions, represented by *e e* in the figure. Upon this middle neck in the pressure rollers, the hook *i* and the saddle *h* immediately bear, as shown in the former *fig.* 401. The card-ends, to the number probably of six, are introduced to the drawing frame either from tin cans, placed at *e e*, *fig.* 403, and at A, *fig.* 402, or from lap-bobbins; and, after passing through it, the ribands or slivers are received either into similar tin cans, as *g*, or upon other lap-bobbins upon the other side. These appendages may be readily conceived, and are therefore not exhibited in all the drawings. Three of the slivers being laid together are again introduced to the one fluted portion *a b*, *fig.* 401, and three other slivers to the other portion. The sloping curved tin or brass plate *s*, *fig.* 402, with its guide pins *t*, serves to conduct the slivers to the rollers. When the two threefold slivers have passed through between the three pairs of rollers, and been thereby properly drawn, they run towards each other in an oblique direction, behind the last roller pair *e f*, *fig.* 401, and unite, on issuing through the conical funnel *m*, *fig.* 402, into a single riband or spongy sliver; which is immediately carried off with equable velocity by two smooth cast-iron rollers, *n o*, *figs.* 402 and 403, and either dropped into a can, or wound upon a large bobbin. The surface speed of these rollers is made a trifle greater than that of the delivery drawing rollers, in order to keep the portion of sliver between them always in an extended state. Four fluted drawing portions are usually mounted in one drawing frame, which are set a-going or at rest together. To save all unnecessary carrying of the cans from the back to the front of the frame, the drawing heads are so placed, that the first and third discharge their slivers at the one side, and the second and fourth at the other. By this arrangement, the cans filled behind one head, are directly pushed aside in front of the next drawing head; by which alternate distribution the work goes on without interruption.

The *fast* pulley *u*, *fig.* 403, by which the whole machine is driven, derives its motion from the main shaft of the mill by means of the band *w*. The similar pulley *z*, which sits loose upon the axis, and turns independently of it, is called the loose pulley; both together being technically styled *riggers*. When the operative desires to stop the machine, he transfers the band from the fast to the loose pulley by means of a lever, bearing a fork at its end, which embraces the band. Upon *y*, four pulleys such as *x* are fixed, each of which sets in motion a drawing head, by means of a band like *w* going round the pulleys *x* and *u*. On account of the inverted position of the heads, which requires the motion of *u* to be inverted, the bands of the first and third heads are open, but those of the second and fourth are crossed. Every head is provided with a loose pulley *v*, as well as the fast pulley *u*, in order to make the one stop or move without affecting the others. The shaft of the pulley *u* is the prolonged shaft of the backmost fluted roller *f*. It carries besides a small pulley *q*, which, by means of the band *r*, and the pulley *p*, *fig.* 402, sets in motion the undermost condensing roller *o*. The upper roller *n* presses with its whole weight upon it, and therefore turns by friction. The toothed wheel-work, by which the motions are communicated from the backmost fluted roller to the middle and front ones, is seen in *fig.* 403.

The wheel *f*, *fig.* 401, of 20 teeth, works in a 44-toothed carrier-wheel, on whose axis there are two smaller wheels; 2 with 26 teeth, and 1 with 22 teeth. The wheel *d*, *fig.* 403 of the middle roller, and the wheel *b* of the front roller, are set in motion by other carrier wheels; the first has 27 teeth, and the last 40. For every revolution of *b*, the roller *d* makes nearly $1\frac{3}{4}$ turns, and the roller *f* 4 revolutions. The top rollers revolve, as we have stated, simply by the friction of contact with the lower ones. Now suppose the diameter of the rollers *b* and *d* to be 1 inch or 12 lines, that of *f* $1\frac{1}{4}$ inches or 15 lines, the surface velocities of the three pairs of rollers in the series will be as 1, $1\frac{3}{4}$, and 5. Every inch of the cotton sliver will be therefore extended between the first and second pairs of rollers into $1\frac{3}{4}$ inches, and between the second and third or delivery pair into 5 inches; and after the sliver has passed through all the four drawing heads, its length will be increased 625 times $= 5 \times 5 \times 5 \times 5$.

The further the drawing process is pushed, the more perfectly will its object be accomplished, namely, the parallelism of the filaments. The fineness of the appearance of the sliver after the last draught depends upon the number of doublings conjointly with the original fineness and number of drawings. The degree of extension may be increased or diminished, by changing the wheels in *fig.* 403, for others with a different number of teeth. Thus the grist or fineness of the sliver may be modified in any desired degree; for, when the subsequent processes of the mill remain the same, the finer the drawings the finer will be the yarn. For spinning coarse numbers or low counts, for example, six card-ends are usually transmitted through the first drawing head, and converted into one riband. Six such ribands again form one in the second draught; six of these again go together into the third sliver; and this sliver passes five-fold through the last draught. By this combination 1080 of the original card-ends are united in the finished drawn sliver $= 6 \times 6 \times 6 \times 5$. The fineness of the sliver is, however, in consequence of these doublings, not increased, but rather diminished. For, by the drawing, the card-end has been made 625 times longer, and so much smaller; by the doubling alone it would have become 1080 times thicker; therefore, the original grist is to the resent as 1 to the fraction $\frac{625}{1080}$; that is, supposing 1072 feet of the riband delivered by the card to weigh one pound, 625 feet, the sliver of the last drawing, will also weigh a pound, which corresponds in fineness to number 0·24, or nearly $\frac{1}{4}$.

The rearmost or last drawing roller has a circumference of nearly 4 inches, and makes about 150 revolutions per minute; hence, each of these drawing heads may turn off 35,000 feet of sliver in 12 hours.

Some manufacturers have lately introduced a double roller beam, and a double draught at the same doubling, into their drawing frames. I have seen this contrivance working satisfactorily in mills where low counts were spun, and where the tube roving frame was employed; but I was informed by competent judges, that it was not advisable where a level yarn was required for good printing calicoes

The loss which the cotton suffers in the drawing frame is quite inconsiderable. It consists of those filaments which remain upon the drawing rollers, and collect, in a great measure, upon the flannel facing of the top and bottom cleaner bars. It is thrown among the top cleanings of the carding engine. When from some defect in the rollers, or negligence in piecing the running slivers, remarkably irregular portions occur in the ribands, these must be torn off, and returned to the lap machine to be carded anew.

The fifth operation may be called the *first spinning process*, as in it the cotton sliver receives a twist; whether the twist be permanent, as in the bobbin and fly frame, or be undone immediately, as in the tube-roving machine. In fact, the elongated slivers of parallel filaments could bear little further extension without breaking asunder, unless the precaution were taken to condense the filaments by a slight convolution, and at the same time to entwine them together. The twisting should positively go no further than to fulfil the purpose of giving cohesion, otherwise it would place an obstacle in the way of the future attenuation into level thread. The combination of drawing and twisting is what mainly characterizes the spinning processes, and with this fifth operation, therefore, commences the formation of yarn. As, however, a sudden extension to the wished-for fineness is not practicable, the draught is thrice repeated in machine spinning, and after each draught a new portion of torsion is given to the yarn, till at last it possesses the degree of fineness and twist proportioned to its use.

The preliminary spinning process is called *roving*. At first the torsion is slight in proportion to the extension, since the solidity of the still coarse sliver needs that cohesive aid only in a small degree, and looseness of texture must be maintained to facilitate to the utmost the further elongation.

404

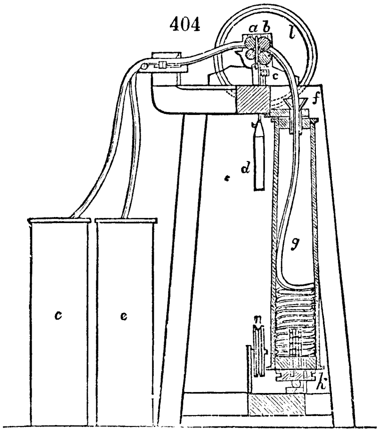


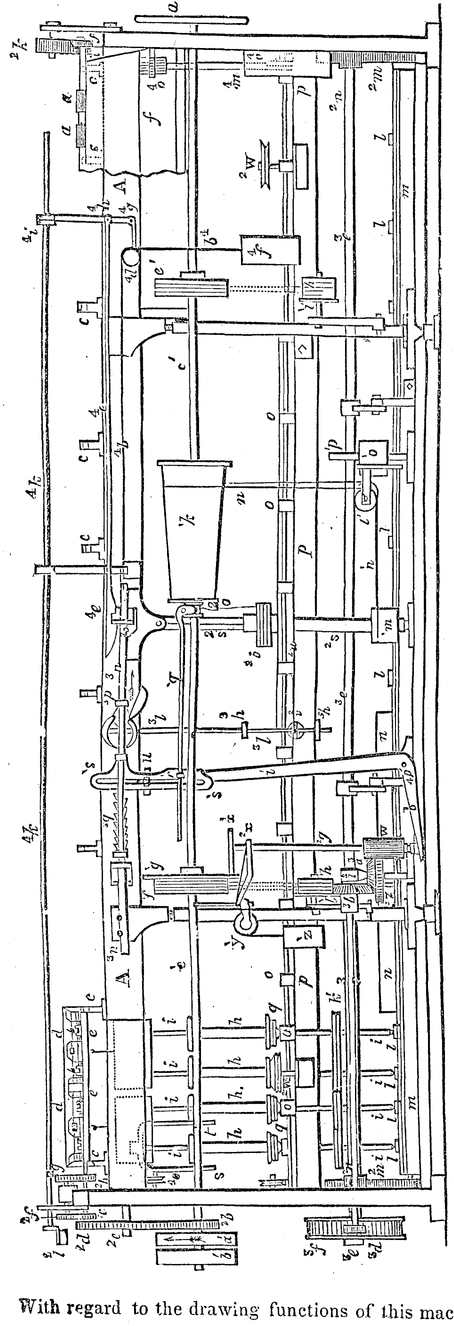
Fig. 404 is a section of the can roving frame, the ingenious invention of Arkwright, which, till within these 14 years, was the principal machine for communicating the incipient torsion to the spongy cord furnished by the drawing heads. It differs from that frame in nothing but the twisting mechanism; and consists of two pairs of drawing rollers, *a* and *b*, between which the sliver is extended in the usual way; *c* are brushes for cleaning the rollers; and *d* is the weight which presses the upper set upon the lower. The wiping covers (not shown here) rest upon *a b*. The surface speed of the posterior or second pair of rollers is 3, 4, or 5 times greater than that of the front or receiving pair, according to the desired degree of attenuation. Two drawn slivers were generally united into one by this machine, as is shown in the figure, where they are seen coming from the two cans *e e*, to be brought together by the pressure rollers, before they reach the drawing rollers *a b*. The sliver, as it escapes from these rollers, is conducted into the revolving conical lantern *g*, through the funnel *f* at its top. This lantern-can receives its motion by means of a cord passing over a pulley *k*, placed a little way above the step on which it turns. The motion is steadied by the collet of the funnel *f*, being embraced by a brass busk. Such a machine generally contained four drawing heads, each mounted with two lanterns; in whose side there was a door for taking out the conical coil of roving.

The motion imparted to the back roller by the band pulley or rigger *m*, was conveyed to the front one by toothed wheel work.

The vertical guide pulley at bottom, *n*, served to lead the driving band descending from the top of the frame round the horizontal whorl or pulley upon the under end of the lantern. The operation of this can-frame was pleasing to behold; as the centrifugal force served both to distribute the soft cord in a regular coil, and also to condense a great deal of it most gently within a moderate space. Whenever the lantern was filled, the tenter carried the roving to a simple machine, where it was wound upon bobbins by hand. Notwithstanding every care in this transfer, the delicate texture was very apt to be seriously injured, so as to cause corresponding injuries in every subsequent operation, and in the finished yarn. Messrs. Cocker and Higgins, of Salford, had the singular merit, as I have said, of superseding that beautiful but defective mechanism, which had held a prominent place in all cotton mills from almost the infancy of the factory system, by the following apparatus.

The Bobbin and Fly frame is now the great roving machine of the cotton manufac ture; to which may be added, for coarse spinning, the tube roving frame. Of such a complicated machine as the bobbin and fly frame, it is not possible to give an adequately detailed description in the space due to the subject in this Dictionary. Its mechanical combinations are, however, so admirable as to require such an account as will make its functions intelligible by the general reader.

405



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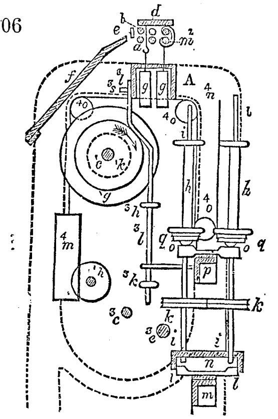
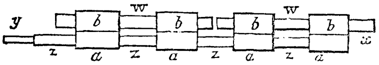


Fig. 405 exhibits a back view of this machine; and *fig.* 406 a section of some of the parts not very visible in the former figure. The back of the machine is the side at which the cotton is introduced between the drawing rollers.

The cans, or lap-bobbins filled with slivers at the drawing frame, are placed in the situation marked B, *fig.* 406, in rows parallel with the length of the machine. The sliver of each can, or the united slivers of two contiguous cans, are conducted upwards along the surface of a sloping board *f*, and through an iron staple or guide *e*, betwixt the usual triple pair of drawing rollers, the first of which is indicated by *a*, *b*. In *fig.* 405, for the purpose of simplifying the figure, the greater part of these rollers and their subordinate parts are omitted. After the slivers have been sufficiently extended and attenuated between the rollers, they proceed forwards, towards the spindles *i i i*, where they receive the twist, and are wound upon the bobbins *h*. The machine delineated contains thirty spindles, but many bobbin and fly frames contain double or even four times that number. Only a few of the spindles are shown in *fig.* 405, for fear of confusing the drawing.

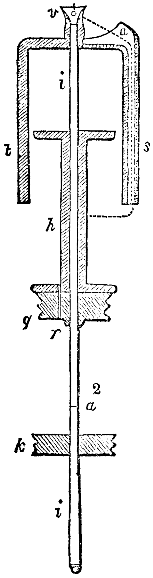
With regard to the drawing functions of this machine, I have already given abundant explanation, so far as the properties and operation of the rollers are concerned. The frame-work of this part of the machine, called the *roller-beam*, is a cast-iron bench upon which nine bearers, *c*, are mounted for carrying the rollers. The fluted rollers *a a a*, *fig.* 407, are constructed in four pieces for the whole length, which are parted from each other by thinner smooth cylindric portions, *z*, called necks. Seven such partings for four rollers, and one parting for two rollers, constitute together the 30 fluted rollers of which the whole series consists. The coupling of these roller subdivisions into one cylinder, is secured by the square holes *x*, and square pins *y*, *fig.* 407, which fit into the holes of the adjoining subdivision. The top or pressure rollers *b*, are two-fold over the whole set; and the weighted saddle presses upon the neck *w*, which connects every pair, as was already explained under *fig.* 402. These weights *g g*, *fig.* 406, are applied in this as in the *drawing frame*; *d* are the bars faced with flannel for cleaning the top rollers. A similar bar is applied beneath the rollers, to keep the flutings clean.

407



The structure and operation of the spindles *i* may be best understood by examining the section *fig.* 408. They are made of iron, are cylindrical from the top down to *a*2, but from this part down to the steel tipped rounded points they are conical. Upon this conical portion there is a pulley *k*, furnished with two grooves in its circumference, in which the cord runs that causes the spindle to revolve. The wooden bobbin *h* is slid upon the cylindrical part, which must move freely upon it, as will be presently explained. To the bobbin another two-grooved pulley or whorl *g* is made fast by means of a pin *r*, which passes through it; by removing this pin, the bobbin can be instantly taken off the spindle. The upper end of the spindle bears a fork *s t*, which may be taken off at pleasure by means of its left-handed screw; this fork, or flier, has a funnel-formed hole at *v*. One arm of the fork is a tube, *s*, *u*, open at top and bottom; the leg, *t*, is added merely as a counterpoise to the other. In *fig.* 406, for the sake of clearness, the forks or fliers of the two spindles here represented are left out; and in *fig.* 405, only one is portrayed for the same reason. It is likewise manifest from a comparison of these two figures that the spindles are alternately placed in two rows, so that each spindle of the back range stands opposite the interval between two in the front range. The object of this distribution is economy of space, as the machine would need to be greatly longer if the spindles stood all in one line. If we suppose the spindles and the bobbins (both of which have independent motions) to revolve simultaneously and in the same direction, their operation will be as follows: The sliver, properly drawn by the fluted rollers, enters the opening of the funnel *v*, proceeds thence downwards through the hole in the arm of the fork, runs along its tube *u*, *s*, and then winds round the bobbin. This path is marked, in *fig.* 408, by a dotted line.

408



The revolution of the spindles in the above circumstances effects the twisting of the sliver into a soft cord; and the flier *s*, *t*, or particularly its tubular arm *s*, lays this cord upon the bobbin: Were the speed of the bobbins equal to that of the spindles, that is, did the bobbin and spindle make the same number of turns in the same time, the process would be limited to mere twisting. But the bobbin anticipates the fliers a little, that is, it makes in a given time a somewhat greater number of revolutions than the spindle, and thereby effects the continuous winding of the cord upon itself. Suppose the bobbin to make 40 revolutions, while the spindle completes only 30; 30 of these revolutions of the bobbin will be inoperative towards the winding-on, because the fliers follow at that rate, so that the cord or twisted sliver will only be coiled 10 times round the bobbin, and the result as to the winding-on will be the same as if the spindle had stood still, and the bobbin had made 40 — 30 = 10 turns. The 30 turns of the spindles serve, therefore, merely the purpose of communicating twist.

The mounting and operation of the spindles are obviously the same as they are upon the household flax wheel. In the bobbin and fly frame there are some circumstances which render the construction and the winding-on somewhat difficult, and the mechanism not a little complicated. It may be remarked, in the first place, that as the cord is wound on, the diameter of the bobbin increases very rapidly, and therefore every turn made round it causes a greater length of roving to be taken up in succession. Were the motions of the bobbins to continue unchanged in this predicament, the increased velocity of the winding-on would require an increased degree of extension, or it would occasion the rupture of the cord, because the front fluted rollers move with uniform speed, and therefore deliver always the same length of sliver in the same time. It is therefore necessary to diminish the velocity of the bobbins, or the number of their turns, in the same proportion as their diameter increases, in order that the primary velocity may remain unchanged. Moreover, it is requisite for the proper distribution of the cord upon the bobbin, and the regular increase of its diameter, that two of its successive convolutions should not be applied over each other, but that they should be laid close side by side. This object is attained by the up and down sliding motion of the bobbin upon the spindle, to the same extent as the length of the bobbin barrel. This up and down motion must become progressively slower, since it increases the diameter of the bobbin at each range, by a quantity equal to the diameter of the sliver. What has now been stated generally, will become more intelligible by an example.

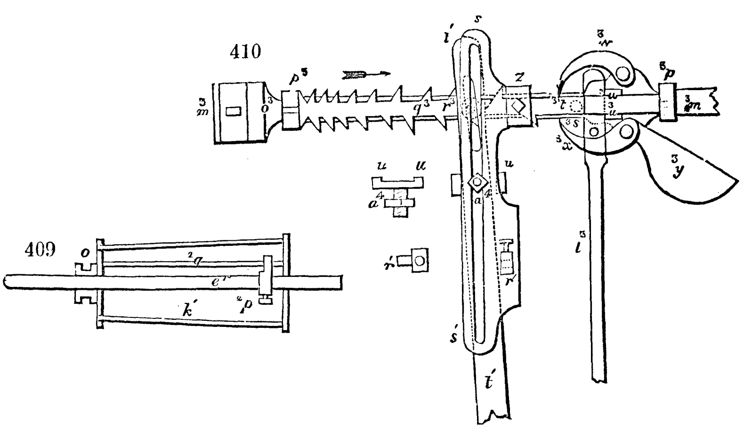
Let it be assumed that the drawing rollers deliver, in 10 seconds, 45 inches of roving, and that this length receives 30 twists. The spindles must, in consequence, make 30 revolutions in 10 seconds, and the bobbins must turn with such speed, that they wind up the 45 inches in 10 seconds. The diameter of the bobbin barrels being 1½ inches, their circumference of course 4½ inches, they must make 10 revolutions more in the same time than the spindles. The effective speed of the bobbins will be thus $30+10=40$ turns in 10 seconds. Should the bobbins increase to 3 inches diameter, by the winding-on of the sliver, they will take up 9 inches at each turn, and consequently 45 inches in 5 turns. Their speed should therefore be reduced to $30+5=35$ turns in 10 seconds. In general, the excess in number of revolutions, which the bobbins must make over the spindles, is inversely as the diameter of the bobbins. The speed of the bobbins must remain uniform during the period of one ascent or descent upon the spindle, and must diminish at the instant of changing the direction of their up and down motion; because a fresh range of convolutions then begins with a greater diameter. When, for example, 30 coils of the sliver or roove are laid in one length of the bobbin barrel, the bobbin must complete its vertical movement up or down, within 30 seconds in the first case above mentioned, and within 60 seconds in the second case.

The motions of the drawing rollers, the spindles, and bobbins, are produced in the following manner:—A shaft *c'*, *figs.* 405 and 406, extending the whole length of the machine, and mounted with a fly wheel *d'*, is set in motion by a band from the running pulley upon the shaft of the mill, which actuates the pulley *a'*. *b'* is the loose pulley upon which the band is shifted when the machine is set at rest. Within the pulley *a'*, but on the outside of the frame, the shaft *c'* carries a toothed wheel b^2 with 50 teeth, which by means of the intermediate wheel c^2 turns the wheel d^2 upon the prolonged shaft of the backmost fluted roller (m^2, *fig.* 406.) This wheel d^2 has usually 54 teeth; but it may be changed when the roove is to receive more or less twist; for as the spindles revolve with uniform velocity, they communicate the more torsion the less length of sliver is delivered by the rollers in a given time. Upon the same shaft with d^2, a pinion e^2 of 32 teeth is fixed, which works in a wheel f^2 of 72 teeth. Within the frame a change pinion g^2 is made fast to the shaft of f^2. This pinion, which has usually from 24 to 28 teeth, regulates the drawing, and thereby the fineness or *number* of the roving. It works in a 48-toothed wheel h^2 upon the end of the backmost fluted roller *a*, *fig.* 406. The other extremity of the same roller, or, properly speaking, line of rollers, carries a pinion l^2, furnished with 26 teeth, which, by means of the broad intermediate wheel k^2, sets in motion the pinion i^2 of 22 teeth upon the middle roller. When the diameter of all the drawing rollers is the same, suppose 1 inch, their proportional velocities will be, with the above number of teeth in the wheel work, if g^2 have 24 teeth, as 1 : 1·18 : 4·5; and the drawn sliver will have 4½ times its original length. The front or delivery roller of the drawing frame is of late years usually made 1¼ or 1⅜ inches in diameter. If 625 feet of the sliver from the drawing frame weighed one pound, 2790 feet of the roving will now go to this weight, and the number will be 1·12; that is, 1 hank and 12 hundredths to the pound. The front pair of fluted rollers makes about 90 revolutions, and delivers 282·6 inches of roving in the minute, when of one inch diameter.

The spindles *i* (*figs.* 405 and 406), rest, with their lower ends, in steps *l*, which are fixed in an immoveable beam or bar *m*. To protect it from dust and cotton filaments, this beam is furnished with a wooden cover *n*, in which there are small holes for the passage of the spindles right over the steps. In *fig.* 405, two of the eight covers *n*, which compose the whole range *m*, are removed to let the steps be seen. The cylindrical part of each spindle passes through a brass ring *o*; and all these 30 rings, whose centres must be vertically over the steps *l*, are made fast to the copping beam *p*. This beam is so called, because it is destined not merely to keep the spindles upright by the rings attached to it, but, at the same time, to raise and lower along the spindles the bobbins which rest on these rings; for which purpose the two racks, or toothed bars m^2 m^2 made fast to it, are designed, as will be presently explained. To effect the revolution of the spindles, there are attached to the main shaft *c′* two whorls or pulleys *e′ f′*, each bearing four grooves of equal diameter. Each of these pulleys puts one half of the spindles in motion, by means of a cord, which, after going round the whorls *k*, turns four times about the pulleys of the shaft *c′*. Two guide pulleys *h′*, each four-grooved, and two others *i′*, with a single groove, which turn independently of the others, upon the above shaft, serve to give the whorl cords the proper direction, as well as to keep them tight. The spindles revolve 200 times or thereby in the minute; and therefore impart two turns or twists to every three inches of the roving.

The revolution of the bobbins is independent of that of the spindles, although it likewise proceeds from the shaft *c′*, and differs from it in being a continually retarded motion. The simplest method of effecting this motion, is by means of the wooden or tin plate cone *k″*, which revolves equally with the shaft *c′*, and at the same time slides along it.

The manner in which this operates is shown in section in *fig.* 409. Here we perceive the rod q^2, which extends from the base toward the narrow end of the truncated cone, and p^2 a forked bearer or carrier made fast to the shaft *c′* by a screw, which compels the cone, by means of that rod, to obey the movements of *c′*. In the large end of the cone there is an aperture, through which the bearer can be got at. The smaller end carries outside a projection o^2, provided with a groove, which is embraced by the forked end of a rod *q′*, *fig.* 410, that serves to shove the cone along upon the shaft *c′*. Directly under the cone, there is an upright round pillar *p′*, upon which the holder *o′* of the two guide pulleys *l′* is adjustable. A bar r^2 placed along-side of the holder, prevents its turning round, but allows it to slide along *p′* by friction. The weight of the holder and the pulley is sufficient to distend the endless band *n′*, which runs from the cone *k′*, through under the pulley *l′*, and round the small drum *m′* on the shaft s^2. A pulley or whorl t^2, with four grooves, is made fast by means of a tube to this shaft, and slides along it backwards and forwards, without ever ceasing to follow its revolutions. The shaft possesses for this purpose a long fork, and the interior of the tube a corresponding tongue or catch. There is besides upon the tube beneath the pulley, at u^2, a groove that goes round it, in which the staple or forked end of an arm like v^2, *fig.* 410, made fast to the copping beam *p*, catches. By the up and down movement of that beam, the pulley t^2 takes along with it the arm that embraces the tube, which therefore rises and falls equally with the bobbins *h′*, and their pulleys or whorls *q*. This is requisite, since the bobbins are made to revolve by the pulleys t^2, by means of two endless cords or bands.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The most intricate part of the mechanism is the adjustment, by which the revolution of the bobbins is continually retarded, and their up and down, or copping motion, along the spindles, is also retarded in like proportion. The vertical pulley *f′* (towards the left end of the shaft *c*) has at its right side a somewhat larger *disc* or sheave *g′*, with a perfectly uniform, but not a very smooth surface. Upon this sheave, a smaller horizontal pulley *x′* rubs, whose upper face is covered with leather to increase the friction The under end of the shaft y^2 of the pulley *x′* turns in a step, which is so connected with the arm *v′* of the large bent lever *t′ v′*, that it always stands horizontally, whatever direction the arms of that lever may assume. The shaft y^2 is steadied at top by an annular holder or bush, which embraces the fast arm x^2 with its forked end. Upon its opposite side, this arm carries a pulley y^2, upon which a cord goes, that is made fast to the holder of the shaft y^2, and loaded with the weight z'. The weight presses the pulley x' against the surface of g', in such wise as to effect the degree of friction necessary in order that the revolution of g' may produce an uninterrupted revolution in x'. A pinion w', whose length must be equal at least to the semi-diameter of the sheave g', is placed upon the under end of the shaft y^2. It has 22 teeth, and takes into a 62-toothed horizontal wheel z^2. Upon the upper end of this wheel the conical pinion a^3 is made fast, which may be changed for changing the speed, but usually has from 28 to 30 teeth. By this pinion the conical wheel b^3 is turned, which has 30 teeth, and whose shaft is c^3. This shaft carries upon its opposite end a six-leaved pinion, d^3, which takes into the calender wheel f^3, formed with cogs like a trundle, upon the long shaft e^3. In *fig.* 411 the wheel f^3 is exhibited with its pinion d^3. Here we may remark, that in the circumference of the wheel there is a vacant place, g^3, void of teeth. When, by the motion of the wheel, the pinion comes opposite to this opening, it turns round about the last tooth of the wheel, falls into the inside of the toothed circle marked by the dotted lines, and thus gives now an inverse movement to the wheel f^3, while itself revolves always in the same direction. This reversed motion continues till the opening g^3 comes once more

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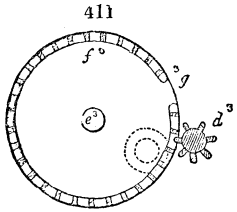

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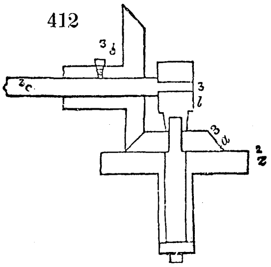

opposite to the pinion, when this turns round about the last tooth of that side, and begins again to work in the exterior teeth. Thus, by the uniform motion of d^3 and its dependant parts, the wheel f^3, with its shaft e^3, revolves alternately to the right hand and the left. That this result may ensue, the shaft c^3 of the pinion must be able to slide endwise, without losing its hold of a^3 and b^3. This adjustment is effected by placing the end of the said shaft, nearest b^3, in a box or holder i^3, in which it can turn, and which forms a vertical tube to this box, as a downward prolongation which is fixed to the tail of the conical pinion a^3. *Fig.* 412 shows this construction in section upon an enlarged scale. The second bearer of the shaft nearest d^3, must possess likewise the means of lateral motion. When therefore the pinion d^3 shifts through the opening of the wheel f^3 outwards or inwards, its shaft c^3, makes a corresponding small angular motion upon the pivot of a^3, by means of the tube i^3; a^3 and b^3 remain thereby completely in gear with one another.

The above-described alternate revolutions of the wheel f^3 serve to produce the up and down motions of the bobbins. The shaft e^3 has for this purpose two pinions n^2 n^2, which work in the rack teeth m^2 m^2 of the copping rail p, and thus alternately raise and sink it with the bobbins which rest upon it. The weight of the copping beam and all its dependant parts, is poised by two counterweights m^4, whose cords run over the pulleys o^4 o^4 o^4, *fig.* 405, and have their ends made fast to the frame, so as to make the upward motion as easy as the downward. The two upper pulleys out of the three of each weight are fixed to the frame; the under one, round which the cord first runs, is attached to the copping beam, rising and falling along with it.

As long as the friction disc x' remains at the same height, the pulley g' derives its motion from the same circle of the said disc, and the up and down motion of the copping beam is also uniform. But when that disc ascends so as to describe with its edge a small circle upon the face of g', its motion must become proportionally more slow. This is the method, or principle of retarding the copping motions of the bobbins. It has been shown, however, that the rotation of the bobbins should be also retarded in a progressive manner. This object is effected by means of the cone k', which, as the band n progressively approaches towards its smaller diameter, drives the pulleys or whorls q of the bobbins with decreasing speed, though itself moves uniformly quick with the shaft c. To effect this variation, the cone is shifted lengthwise along its shaft, while the band running upon it remains continually in the same vertical plane, and is kept distended by the weight of the pulley o'. The following mechanism serves to shift the cone, which may be best understood by the aid of the figures 413, 414, and 410. A long cast iron bar m^3,

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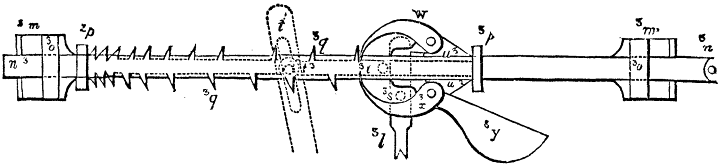
which bears two horizontal projecting puppets, $o^3\ o^3$, is made fast to the front upright face of the copping beam A. Through the above puppets a cylindrical rod n^3 passes freely

413



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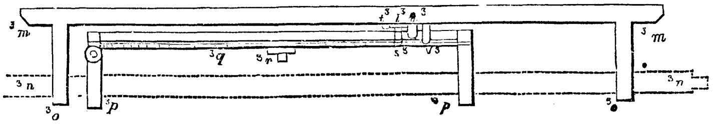


which is left out in *fig.* 410, that the parts lying behind it may be better seen. Upon this rod there is a kind of fork, $p^3\ p^3$, to which the alternating rack bars q^3 are made fast. The teeth of these racks are at unequal distances from each other, and are so arranged, that each tooth of the under side corresponds to the space between two teeth in the upper side. Their number depends upon the number of coils of roving that may be required to fill a bobbin; and consists in the usual machines of from 20 to 22. The rod n^3 may be shifted in the puppet o^3, like the fork p^3 of the rack-rod, upon the rod n^3, and along the surface of m^3, where two wings $u^3\ u^3$ are placed, to keep the fork in a straight direction. Upon the bar m^3, there are the pivots or fulcra of two stop catches $w^3\ x^3$, of which the uppermost presses merely by its own weight, but the undermost by means of a counterweight y^3, against the rack, and causes them thus to fall in between the teeth. In *fig.* 414, v^3 shows the pivot of the catch or detent w^3 by itself, the detent itself being omitted, to render the construction plainer. A pushing rod l^3, upon which there is a pin above at s^3, that passes behind the rack rod, between this and the bar m^3, has for its object to remove at pleasure the one or the other of the two catches; the upper, when the upper end of the rod pushes against it; the under, by means of the above mentioned pin s^3. Both the catches are never raised at once, but either the under or the upper holds the rack bar fast, by pressing against one of the teeth. The vertical motion up or down, which the rod l^3 must take to effect the lifting of the catches, is given to it from the copping beam *p*; since upon it a horizontal arm v^2, *fig.* 414, is fixed, that lays hold of that rod. Upon the pushing rod are two rings, h^3 and k^3, each made fast by a screw. When the copping beam is in the act of going up, the arm v^3 at the end of this movement, pushes against the ring h^3, raises up the rod l^3, and thus removes the catch w^3, *fig.* 410, from the teeth of the rod q^3, before which it lies flat. At the descent of the copping rail, v^2 meets the ring k^3, when the motion in this direction is nearly completed, draws down the rod l^3 a little, by means of the same, and thereby effects the removal of the catch x^3, *fig.* 414, from the rod q^3. Every time that one of the catches is lifted, the rack recovers its freedom to advance a little bit in the direction of the arrow; so far, namely, till the other catch lays hold upon the tooth that next meets it. The reason is thus manifest why the teeth of the upper and under sides of the bar q^3 are not right opposite to each other, but in an alternate position.

From the rack-bar, the sliding of the cone k', and the raising of the shaft y^2, each by minute steps at a time, is produced as follows:—

A large rectangular lever t^1, v^1, whose centre of motion is at p^4, has at the upper end of its long arm t^1, a long slot through which a stud r^3 upon the rack q^3 goes, (*figs.* 413, 414, 410,) so that the lever must follow the motions of the rack bar. The end of the short arm of the lever bears, as already mentioned, the step of the shaft y^2; hence the friction disc x^1 will be raised in proportion as the rack bar advances, and will come nearer to the middle point of g^1; consequently, its revolution and the shifting of the bobbins will become slower. Upon the cylindrical rod n^3, the piece $s^1\ s^1$ furnished with a long slot is made fast, by means of a tube z^3, (*fig.* 410,) and a screw. A fork $u\ u$, which by means of the screw nut a^4 is made fast in the slot, embraces the arm t^1 of the bent lever; and a tube r^1 riveted to the surface of s^1, is destined to take up the draw rod q^1 of the cone k^1, *fig.* 410. A weight f^4, whose cord b^4 is made fast to the cylindrical rod n^3, endeavors to draw this rod continually in the direction of the arrow. In consequence of this arrangement, every time that the pushing bar l^3 lifts up one of the catches, the cone k^1, the lever $t^1\ v^1$, and by it the rack bar q^3, are set in motion. It is obvious, that the motion of the cone may be made greater or less, according as the fork *u u* is fixed further up or down in the slot of s^1.

The number of the teeth upon the bar q^3 is so ordered, that the bobbins are quite full when the last tooth has reached the catch and is released by it. The rack bar, being restrained by nothing, immediately slides onwards, in consequence of the traction of the weight f^4, and brings the machine to repose by this very movement, for which purpose the following construction is employed. A rectangular lever which has its centre of motion in g^4 is attached to the side face of the beam A, and has at the end of its horizontal arm a pulley d^4, over which the cord b^4 of the counterweight f^4 is passed. The end of the perpendicular arm is forked and embraces the long and thin rod k^4, to whose opposite end the fork l^4 is made fast. Through this fork the band which puts the machine in motion passes down to the pulley a^1. With the bent lever another rod c^4 is connected at h^4, which lies upon the puppet e^3 with a slot at e^4, and hereby keeps the lever g^4 in its upright position notwithstanding the weight f^4. In the moment when, as above stated, the rack bar q^3 becomes free, the arm p^3 of its fork pushes in its rapid advance against the under oblique side of e^4, raises this rod, and thereby sets the lever g^4 free, whose upright arm bends down by the traction of the weight, drives the rod k^4 before it into the ring i^4 fastened to it, and thus, by means of the fork l^4, shifts the band upon the loose pulley b^1. But the machine may be brought to repose or put out of gear at any time merely by shifting the rod k^4 with the hand.

The operation of the bobbin and fly frame may be fully understood from the preceding description. A few observations remain to be made upon the cone k^1, the rack-bar q^3, and the speed of the work.

When we know the diameter of the empty bobbins, and how many turns they should make in a given time in order to wind-on the sliver delivered by the fluted rollers and the spindles; when we consider the diameters of the spindle pulleys *q*, and t^2, as also the drum m^1, *fig.* 405, we may easily find the diameter which the cone must have for producing that number of turns. This is the diameter for the greatest periphery of the base. The diameter of the smaller is obtained in the same way, when the diameter of the bobbins before the last winding-on, as well as the number of turns necessary in a given time, are known.

A bobbin and fly frame of the construction just described delivers from each spindle in a day of twelve hours, from 6 to 8 lbs. of roving of the fineness of 1½ English counts. One person can superintend two frames, piece the broken slivers, and replace the full bobbins by empty ones. The loss of cotton wool in this machine consists in the portions carried off from the torn slivers, and must be returned to the lapping machine.

The fine bobbin and fly frame does not differ essentially from the preceding machine. The rovings from the coarse bobbin and fly frame are placed in their bobbins in a frame called the *creel*, behind and above the roller beam, two bobbins being allowed for one fluted portion of the rollers. These rovings are united into one, so as to increase the uniformity of the slivers.

The invention of the beautiful machine above described is due to Messrs. Cocker and Higgins, of Manchester, and as lately improved by Henry Houldsworth, jun., Esq., it may be considered the most ingeniously combined apparatus in the whole range of productive industry.

In the fine roving frame the sliver is twisted in the contrary direction to that of the coarse roving frame. For this reason the position of the cone is reversed, so as to present in succession to the band, or strap, diameters continually greater, in order that the rotation of the bobbins may be accelerated in proportion as their size is increased, because here the flier and the bobbin turn in the same direction, and the winding-on is effected by the precession of the bobbin; but if the winding-on took place by its falling behind, as in the coarse bobbin and fly frame, that is, if the flier turned less quickly than the bobbin, the rotatory speed of the bobbin would be uniformly retarded; in which case the cone would be disposed as in the coarse frame.

When, by any means whatever, a uniform length of thread is delivered by the rollers in a given time, the bobbin must wind it up as it is given out, and must therefore turn with a speed decreasing with the increase of its diameter by successive layers of thread. Hence proceeds the proposition, that the velocity of the bobbin must be in the inverse ratio of its diameter, as already explained.

With respect to the bobbin and fly frame, the twist is given to the sliver by means of a spindle, or flier, which turns in the same direction with the bobbin, but quicker or slower than it, which establishes two predicaments. The first case is where the flier turns faster than the bobbin. Here the winding-on goes in advance, as in the coarse roving frame, or as in throstle spinning, where the yarn is wound on merely in consequence of the friction of the lower disc or washer of the bobbin upon the copping rail, and of the drag of the yarn. The second case is where the flier revolves more slowly than the bobbin. Here the winding goes on in arrear, and as the bobbin turns faster, it must receive a peculiar motion, which is uniformly retarded in the ratio of its increase of diameter. This is the case with the fine bobbin and fly frame. When the cone is placed as in *fig*. 405, the winding-on, in either the coarse or fine frame, results from the difference, whether greater or less, between the rotatory speed of the flier and bobbin.

The motion of the bobbin and spindle is simultaneous, and takes place in the same direction, with a difference varying more or less with the varying diameters of the bobbins. To rénder the matter still clearer, suppose for a moment the spindle to be motionless, then the bobbin must revolve with such a speed as to lap-on the roving as fast as the rollers deliver it. The sliver comes forward uniformly; but the bobbin, by its increase of diameter, must revolve with a speed progressively slower. Now, suppose the spindle set a-whirling, it is obvious that the bobbin must add to the movement requisite for winding-on the sliver, that of the spindle in the case of winding-on in arrear, or when it follows the fliers, and subtract its own motion from the twisting motion of the spindles, in the case of winding-on in advance, that is, when the bobbin precedes or turns faster than the fliers; for the diameter of the bobbin being 1½ inches, 10 turns will take up 45 inches. Deducting these 10 turns from the 30 made by the spindle in the same time, there will remain for the effective movement of the bobbin only 20 turns; or when the diameter of the bobbin becomes 3 inches, 5 turns will take up the 45 inches, if the spindle be at rest; but if it makes 30 turns in the time, the effective velocity of the bobbin will be 25 turns, = 30 — 5. Hence in the fine bobbin and fly frame, the number of turns of the spindle, *minus* the number of turns made by the bobbin in equal times, is in the inverse ratio of the diameter of the bobbin. We thus perceive, that in the coarse frame the bobbin should move faster than the spindle, and that its speed should always diminish; whilst in the fine frame the bobbin should move slower than the spindle, but its speed should always increase. It is easy to conceive, therefore, why the cones are placed in reverse directions in the two machines. Not that this inversion is indispensably necessary; the cone of the fine roving frame might, in fact, be placed like that of the coarse roving frame; but as the torsion of the roving becomes now considerable, and as on that account the bobbin would need to move still faster, which would consume a greater quantity of the moving power, it has been deemed more economical to give its movement an opposite direction.

We mentioned that the twist of the sliver in the fine roving frame was the reverse of that in the coarse; this is a habit of the spinners, for which no good reason has been given.

The divisions of the rack-bar, and the successive diameters of the cone, must be nicely adjusted to each other. The first thing to determine is, how much the rack should advance for every layer or range of roving applied to the bobbin, in order that the cone may occupy such a place that the strap which regulates the pulley barrel may be at the proper diameter, and thus fulfil every condition. The extent of this progressive movement of the rack depends upon the greater or less taper of the cone, and the increase which the diameter of the bobbin receives with every traverse, that is, every layer of roving laid on. But care should be taken not to taper the cone too rapidly, especially in the fine roving frame, because in its progress towards the smaller end the strap would not slide with certainty and ease. We have already shown that the number of effective turns of the bobbin is inversely, as the diameter of the bobbin; or directly, as the successive diameters of the different points of the cone.

H. Houldsworth, jun. Esq. has introduced a capital improvement into the bobbin and fly frame, by his differential or equation-box mechanism, and by his spring fingers, which, by pressing the soft sliver upon the bobbin, cause at least a double quantity to be wound upon its barrel. With the description of his patent equation-box, I shall conclude the description of the bobbin and fly frame.

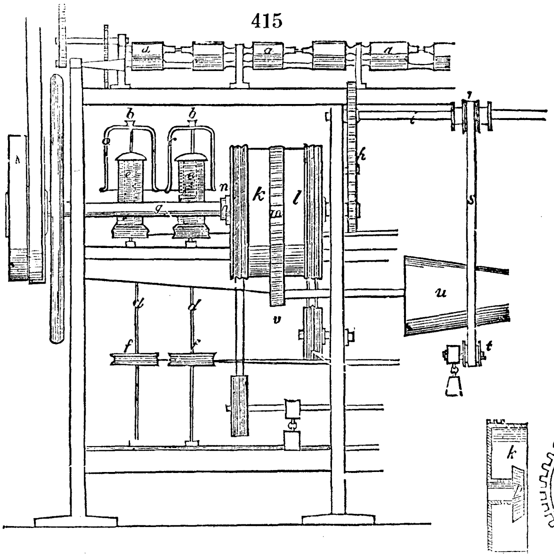
Fig. 415 represents a portion of a fly frame with Mr. Houldsworth's invention. *a a a* are the front drawing rollers, turning upon bearings in the top of the machine, and worked by a train of toothed wheels, in the way that drawing rollers are usually actuated.

From the drawing rollers, the filaments of cotton or other material, *b b*, are brought down to, and passed through the arms of the fliers *c c*, mounted on the tops of the spindles *d d*, which spindles also carry the loose bobbins *e e*. In the ordinary mode of constructing such machines, the spindles are turned by cords or bands passing from a rotatory drum round their respective pulleys or whirls *f*, and the loose bobbins *e*, turn with them by the friction of their slight contact to the spindle, as before said; in the improved machine, however, the movements of the spindles and the bobbins are independent and distinct from each other, being actuated from different sources.

The main shaft of the engine *g*, turned by a band and rigger A as usual, communicates motion by a train of wheels *h*, through the shaft *i*, to the drawing rollers at the reverse end of the machine, and causes them to deliver the filaments to be twisted.

Upon the main shaft *g*, is mounted a cylindrical hollow box or drum-pulley, whence one cord passes to drive the whirls and spindles *f* and *d*. and another to drive the bobbins *e*.

415



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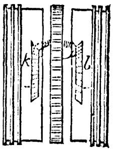

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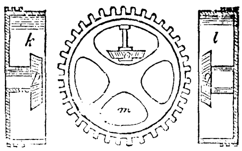


This cylindrical box pulley is made in two parts, *k* and *l*, and slipped upon the axle with a toothed wheel *m*, intervening between them. The box and wheel are shown detached in *fig.* 416, and partly in section at *fig.* 417. That portion of the box with its pulley marked *l*, is fixed to the shaft *g*; but the other part of the box and its pulley *k*, and the toothed wheel *m*, slide loosely round upon the shaft *g*, and when brought in contact and confined by a fixed collar *n*, as in the machine shown at *fig.* 415, they constitute two distinct pulleys, one being intended to actuate the spindles, and the other the bobbins.

In the web of the wheel *m*, a small bevel pinion *o*, is mounted upon an axle standing at right angles to the shaft *g*, which pinion is intended to take into the two bevel pinions *p* and *q*, respectively fixed upon bosses, embracing the shaft in the interior of the boxes *k* and *l*. Now it being remembered that the pinion *q*, and its box *l*, are fixed to the shaft *g*, and turn with it, if the loose wheel *m* be independently turned upon the shaft, with a different velocity, its pinion *o*, taking into *q*, will be made to revolve upon its axle, and to drive the pinion *p*, and pulley box *k*, in the same direction as the wheel *m*; and this rotatory movement of the box *k* and wheel *m*, may be faster or slower than the shaft *g*, and box *l*, according to the velocity with which the wheel *m* is turned.

Having explained the construction of the box pulleys *k* and *l*, which are the peculiar features of novelty claimed under this patent, their office and advantage will be seen by describing the general movements of the machine.

The main shaft *g*, being turned by the band and rigger A, as above said, the train of wheels *h*, connected with it. drives the shaft *i*, which at its reverse end has a pinion (not seen in the figure) that actuates the whole series of drawing rollers *a*. Upon the shaft *i* there is a sliding pulley *r*, carrying a band *s*, which passes down to a tension pulley *t*, and is kept distended by a weight. This band *s*, in its descent, comes in contact with the surface of the cone *u*, and causes the cone to revolve by the friction of the band running against it. The pulley *r* is progressively slidden along the shaft *i*, by means of a rack and weight not shown, but well understood as common in these kind of machines, and which movement of the pulley is for the purpose of progressively shifting the band *s* from the smaller to the larger diameter of the cone, in order that the speed of its rotation may gradually diminish as the bobbins fill by the winding-on of the yarns.

At the end of the axle of the cone *u* a small pinion *v* is fixed, which takes into the teeth of the loose wheel *m*, and, as the cone turns, drives the wheel *m* round upon the shaft *g*, with a speed dependant always upon the rapidity of the rotation of the cone. Now the box pulley *l*, being fixed to the main shaft *g*, turns with one uniform speed, and by cords passing from it over guides to the whorls *f*, drives all the spindles and fliers, which twist the yarns with one continued uniform velocity; but the box pulley *k*, being loose upon the shaft, and actuated by the bevel pinions within, as described, is made to revolve by the rotation of the wheel *m*, independent of the shaft, and with a different speed from the pulley box *l*; cords passing from this pulley box *k*, over guides to small pulleys under the bobbins, communicate the motion, whatever it may be, of the pulley box *k*, to the bobbins, and cause them to turn, and to take up or wind the yarn with a speed derived from this source, independent of, and different from, the speed of the spindle and flier which twist the yarn.

It will now be perceived, that these parts being all adjusted to accommodate the taking up movements to the twisting or spinning of any particular quality of yarn intended to be produced, any variations between the velocities of the spinning and taking up, which another quality of yarn may require, can easily be effected, by merely changing the pinion *v*, for one with a different number of teeth, which will cause the wheel *m*, and the pulley box *k*, to drive the bobbins faster or slower, as would be required in winding-on fine or coarse yarn, the speed of the twisting or spinning being the same.

The rovings or spongy cords, of greater or less tenuity, made on the bobbin and fly, or tube roving frame, are either spun immediately into firm cohesive yarn, or receive a further preparation process in the stretching frame, which is, in fact, merely a mule-jenny, without the second draught and second speed, and therefore need not be described at present, as it will be in its place afterwards.

The *finishing machines* of a cotton mill, which spin the cohesive yarn, are of two classes; 1. the water-twist or throstle, in which the twisting and winding are performed simultaneously upon progressive portions of the roving; and, 2. the mule, in which the thread is drawn out and stretched, with little twist, till a certain length of about 5 feet is extended, then the torsion is completed, and the finished thread is immediately wound upon the spindles into double conical coils called cops.

The water-twist frame, so called by its inventor, Sir R. Arkwright, because it was first driven by water, is now generally superseded by the throstle frame, in which the mechanical spinning fingers, so to speak, are essentially the same, but the mode of communicating the motion of the mill-gearing to them is somewhat different. *Fig.* 418 exhibits a vertical section of the throstle. This machine is double, possessing upon each side of its frame a row of spindles with all their subsidiary parts. The bobbins, filled with rovings from the bobbin and fly, or the tube frame, are set up in the creel *a a*, in two ranges. *b*, *c*, *d*, are the three usual pairs of drawing rollers, through which the yarn is attenuated to the proper degree of fineness, upon the principles already explained. At its escape from the front rollers, every thread runs through a guide eyelet *e* of wire, which gives it the vertical direction down towards the spindles *f*, *g*. The spindles which perform at once and uninterruptedly the twisting and winding-on of the thread delivered by the rollers, are usually made of steel, and tempered at their lower ends. They stand at *g* in steps, pass at *v* through a brass bush or collet which keeps them upright, and revolve with remarkable speed upon their axes. The bobbins *h*, destined to take up the yarn as it is spun, are stuck loosely upon the spindles, and rest independently of the rotation of the spindles upon the copping beam *l*, with a leather washer between. Upon the top of the spindles an iron-wire fork, called a fly or flier, *i*, *k*, is made fast by a left-hand screw, and has one of its forks turned round at the end into a little ring. The branch of the flier at *f* is tubular, to allow the thread to pass through, and to escape by a little hole at its side, in order to reach the eyelet at the end of that fork. From this eyelet *i*, it proceeds directly to the bobbin. By the twirling of the spindle, the twisting of the portion of thread between the front roller *d* and the nozzle *f* is effected. The winding-on takes place in the following way:—Since the bobbin has no other connexion with the spindle than that of the thread, it would, but for it, remain entirely motionless, relatively to the spindle. But the bobbin is pulled after it by the thread, so that it must follow the rotation of the spindle and fly. When we consider that the thread is pinched by the front roller *d*, and is thereby kept fully upon the stretch, we perceive that the rotation of the bobbin must be the result. Suppose now the tension to be suspended for an instant, while the rollers *d* deliver, for example, one inch of yarn. The inertia or weight of the bobbin, and its friction upon the copping beam *l*, by means of the leather washer, will, under this circumstance, cause the bobbin to hang back in a state of rest, till the said inch of yarn be wound on by the whirling of the fly *i*, and the former tension be restored. The delivery of the yarn by the drawing rollers, however, does not take place inch after inch, by starts, but at a certain continuous rate; from whence results a continuous retardation or loitering, so to speak, of the bobbins behind the spindles, just to such an amount that the delivered yarn is wound up at the same time during the rotation.

This process in spinning is essentially the same as what occurs in the fine bobbin and fly frame, but is here simplified, as the retardation regulates itself according to the diameter of the bobbin by the drag of the thread. In the fly frame the employmen.

of this tension is impossible, because the roving has too little cohesion to bear the strain; and hence it is necessary to give the bobbins that independent movement of rotation which so complicates this machine.

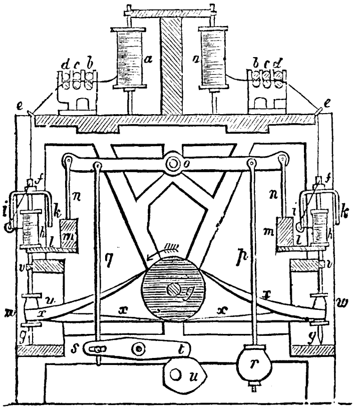
The up and down motion of the bobbins along the spindles, which is required for the equal distribution of the yarn, and must have the same range as the length of the bobbin barrels, is performed by the following mechanism. Every copping rail, *l*, is made fast to a bar *m*, and this, which slides in a vertical groove or slot at the end of the frame, is connected by a rod *n*, with an equal-armed, moveable lever *o*. The rod *p* carries a weight *r*, suspended from this lever; another rod, *q*, connects the great lever *o* with a smaller one *s*, *t*, upon which a heart-shaped disc or pulley, *u*, works from below at *t*. By the rotation of the disc *u*, the arm *t*, being pressed constantly down upon it by the reaction, the weight *r* must alternately rise and fall; and thus the copping rail *l* must obviously move with the bobbins *h* up and down; the bobbins upon one side of the frame rising, as those upon the other sink. Strictly considered, this copping motion should become slower as the winding-on proceeds, as in the fly roving frame; but, on account of the smallness of the finished thread, this construction, which would render the machine complicated, is without inconvenience neglected, with the result merely that the coils of the yarn are successively more sparsely laid on, as the diameter of the bobbin increases.

The movement of the whole machine proceeds from the shaft of a horizontal drum, which drives the spindles by means of the endless bands *x x*. Each spindle is mounted with a small pulley or wharf, *w*, at its lower part, and a particular band, which goes round that wharf or whorl, and the drum *y*. The bands are not drawn tense, but hang down in a somewhat slanting direction, being kept distended only by their own weight. Thus every spindle, when its thread breaks, can readily be stopped alone, by applying a slight pressure with the hand or knee, the band meanwhile gliding loosely round the whorl.

The velocities of rotation of the three drawing rollers are, according to this arrangement, in the proportion of $1 : 1\frac{1}{2} : 8$; and as their diameters are the same, namely, one inch, the elongation of the yarn in spinning is eight fold. If, for example, the roving was of the number $4\frac{1}{2}$, the yarn would become No. 36. The extension of the thread may be changed by changing the wheels of the drawing rollers. To perceive the power of this change, let us put, for example, in the place of the 18-toothed wheel of the back rollers, a wheel with 16 teeth; we shall find that the elongation will amount, in that case, only to $7\frac{1}{2}$ times, whence the number of the yarn would come out $32 = 7\frac{1}{2} \times 4\frac{1}{2}$. The extension by the throstle is extremely various: it amounts, in some cases, to only 4 times; at others to 10, 12, or even 15.

The copping motion of the bobbins is produced in consequence of a bevel pinion working in a small bevel wheel upon an upright shaft; while this wheel gives a slow motion by means of a worm screw to the wheel of the heart-shaped pulley *u*, *fig.* 418.

418



The driving pulley makes about 600 turns in a minute; and as the diameter of the drum *y*, *fig.* 418, is six times the diameter of the spindle wharves *w*, it will give 3600 turns to the spindle in that time. If the pulley be driven faster, for example, 700 times in a minute, it will increase the revolutions of the spindles to 4200. The degree of twist which will be thereby imparted to the yarn, depends, with like speed of spindles, upon the rate at which the soft yarn is delivered by the drawing-rollers; for the quicker this delivery the quicker is the winding-on, and the less twist goes into a given length of yarn. If, for example, the front rollers *d* turn 24 times in a minute, giving out of course 72 inches of yarn in this time, upon which the 3600 revolutions of the spindle are expended, there will be 50 twists to every inch of yarn. By changing the wheel-work of *fig.* 418, or by sticking greater or smaller wharves upon the spindles, the proportion between their velocity and that of the drawing rollers, and thence the degree of twist, can be modified at pleasure.

The number of spindles in a throstle frame 12 feet long is about 60 on each side. The drawing rollers are coupled together as in the bobbin and fly frame, so that each row forms one continuous cylinder. There is a complete roller beam on each side; each of the rollers of the front row is pressed by its top rollers with a weight of ten twelve pounds; but those of the middle and back rows bear weights of only one pound. In the throstles, there is a guide bar which traverses a small way horizontally to the left and right, in front of the roller beam, to lead the thread along different points of the rollers, and thus prevent the leather of the top ones from being grooved by its constant pressure in one line.

For the service of 240 spindles, in two double frames, one young woman and an assistant piecer are sufficient. They mend the broken ends, and replace the empty bobbins in the creel with full ones, and the full bobbins of the throstle by empty ones. The average quantity of yarn turned off in a week of 69 hours is about 24 hanks per spindle of 30's twist. Throstle yarn is of a firm wiry quality, adapted to the warps of fustians and other strong stuffs, as well as to the manufacture of stockings and sewing thread.

There are many modifications of the throstle system besides the one above described; the most celebrated of which are Danforth's, called the American throstle, Montgomery's, and Gore's. I must refer for an account of them to my work entitled "The Cotton Manufacture of Great Britain," where they are minutely described and illustrated with accurate figures.

Mule-spinning.—The general principles of the mule have been already stated. This machine is so named because it is the offspring, so to speak, of two older machines, the jenny and the water-frame. A mule is mounted with from 240 to 1000 spindles, and pins, of course, as many threads.

419

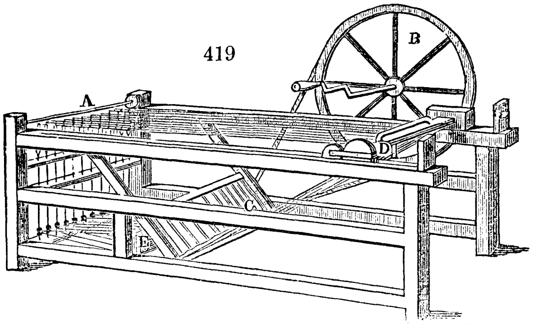


Fig. 419 represents the original *jenny* of Hargreaves, by which one person was enabled to spin from 16 to 40 threads at once. The soft cords of rovings wound in double conical cops upon skewers were placed in the inclined frame at C; the spindles for first twisting and then winding-on the spun yarn were set upright in steps and bushes at A, being furnished near their lower ends with whorls, and endless cords, which were driven by passing round the long-revolving drum of tin plate E. D is the clasp or clove, having a handle for lifting its upper jaw a little way, in order to allow a few inches of the soft roving to be introduced. The compound clove D being now pushed forward upon its friction wheels to A, was next gradually drawn backward, while the spindles were made to revolve with proper speed by the right hand of the operative turning the fly-wheel B. Whenever one *stretch* was thereby spun, the clove frame was slid home towards A; the spindles being simultaneously whirled slowly to take up the yarn, which was laid on in a conical cop by the due depression of the faller wire at A with the spinner's left hand.

420

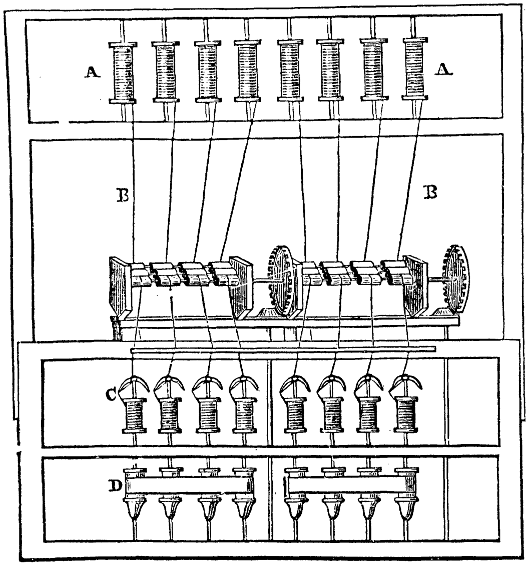


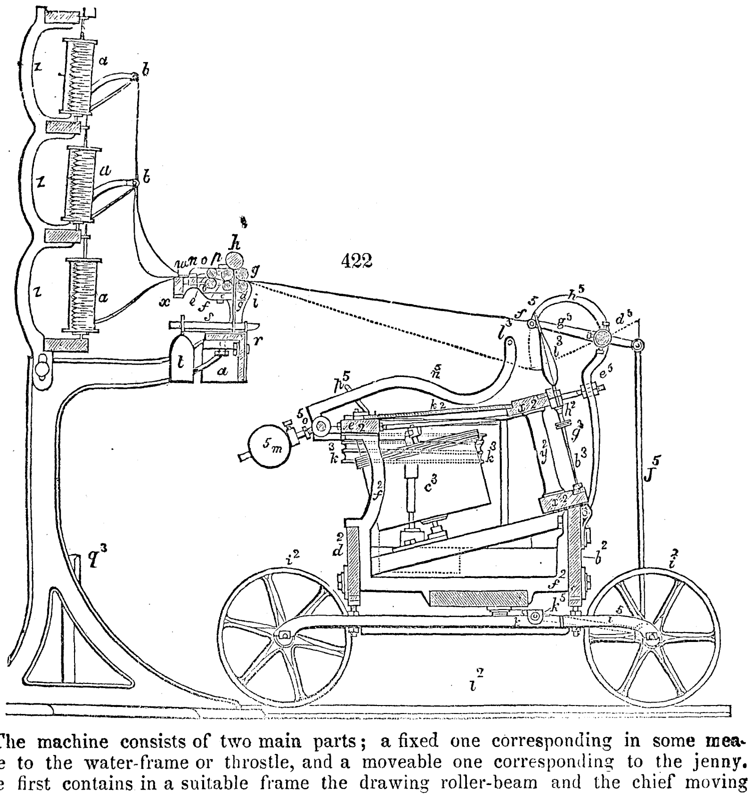
Fig. 420 is a diagram of Arkwright's original *water-frame* spinning machine, called afterwards the *water-twist* *frame.* The rovings mounted upon bobbins in the creel A A, have their ends led through between the three sets of twin rollers below B B, thence down through the eyelet hooks upon the end of the fliers of the spindles C, and finally attached to their bobbins. The spindles being driven by the band D D upon their lower part, continuously twist and wind the finished yarn upon the bobbins; constituting the first unremitting automatic machine for spinning which the world ever saw.

421

Contrast with the above admirable system, the primitive cotton wheel of India, as represented in the annexed figure 421. By the aid of mechanical fingers, one Englishman at his mule can turn off daily more yarn and of far finer quality than 200 of the most diligent spinsters of Hindostan.

Fig. 422 is a transverse section of the mule, in which its principal parts are shown.

422



The machine consists of two main parts; a fixed one corresponding in some measure to the water-frame or throstle, and a moveable one corresponding to the jenny. The first contains in a suitable frame the drawing roller-beam and the chief moving machinery: the second is called the carriage, in which the remainder of the moving mechanism and the spindles are mounted.

The frame of the fixed part consists of two upright sides, and two or more intermediate parallel bearings, upon which the horizontal roller beam *a*, the basis of the drawing rollers is supported. *b*, *c*, *d*, are the three ranges of fluted iron rollers; *e*, *f*, *g*, are the upper iron rollers covered with leather; *h*, the wooden wiper-rollers covered with flannel, which being occasionally rubbed with chalk, imparts some of it to the pressure rollers beneath, so as to prevent the cotton filaments adhering to them. The rollers are made through-put the whole length of the mule in portions containing six flutings, which are coupled together by squared ends fitted into square holes.

The skewers upon which the bobbins containing the rovings from the bobbin and fly or stretching frame are set up, are seen at a^1, a^1, a^1, arranged in three rows in the creel z. The soft threads unwound from these bobbins, in their way to the drawing rollers, pass first through eyelets in the ends of the wire arms b^1, then through the rings or eyes of the guide bar w, and enter between the back pair of rollers. The number of these bobbins is equal to the number of spindles in the mule, and twice as great as the number of fluted portions of the rollers; for two threads are assigned to each portion.

The carriage consists of two cast-iron side pieces, and several cast-iron intermediate similar pieces, such as f^2, which all together are made fast to the planks b^2, c^2, d^2. The top is covered in with the plank k^2. The carriage runs by means of its cast-iron grooved wheels, upon the cast-iron railway l^2, which is fixed level on the floor.

The spindles stand upon the carriage in a frame, which consists of two slant rails x^2, x^2, connected by two slender rods y^2, and which frame may be set more or less obliquely. The lower rail carries the brass steps for the points of the spindles b^3; upon the upper rail brass slips are fixed pierced with holes through which the tops of the spindles play. The spindles are as usual made of steel, perfectly straight, turned truly round, and are all arranged in one plane. To each of them a small wooden or cast-iron whorl g^2 is made fast. They are distributed into groups of 24, and the whorls are arranged at such different heights, that only two of them in each group are upon a level with each other. A small brass head h^2, which every spindle has beneath the upper slant rail of the frame x^2, prevents their sitting down into the step, during their rotation, or sliding off their cop of yarn.

c^3 are drums, mounted in the carriage in a plane at right angles to the plane in which the spindles are placed. At top they have a double groove for a cord to run in, and the motion which they receive from the great fly wheel, or rim of the mule (not visible in this view) they impart to the spindles. Such a drum is assigned to every 24 spindles; and therefore a mule of 480 spindles contains 20 drums. In the middle of the carriage is seen the horizontal pulley k^3, furnished with three grooves, which stands in a line with the drums c^3.

The motion is given to the drums c^3, upon the right hand half of the carriage, by a single endless band or cord which proceeds from the middle groove of the pulley k^3. The rotation of the spindles is produced by a slender cord, of which there are 12 upon each drum c^3; because every such cord goes round the drum, and also every two wharves which stand at the same level upon the spindles. It is obvious that the drums, and consequently the spindles, must continue to revolve as long as the main rim of the mule is turned, whether the carriage be at rest or in motion upon its railway.

If we suppose the carriage to be run in to its standing point, or to be pushed home to the spot from which it starts in spinning, its back plank d^2 will strike the post q^3 upon the fixed frame, and the points of the spindles will be close in front of the roller beam. The rollers now begin to turn and to deliver threads, which receive immediately a portion of their twist from the spindles; the carriage retires from the roller beam with somewhat greater speed than the surface speed of the front rollers, whereby the threads receive a certain degree of stretching, which affects most their thicker and less twisted portions, and thereby contributes greatly to the levelness of the yarn. When the carriage has run out to the end of its course, or has completed a stretch, the fluted rollers suddenly cease to revolve (and sometimes even beforehand, when a second stretch is to be made), but the spindles continue to whirl till the fully extended threads have received the proper second or after-twist. Then the carriage must be put up, or run back towards the rollers, and the threads must be wound upon the spindles.

This is the order of movements which belong to the mule. It has been shown how the rotation of the spindles is produced.

For winding-on the yarn the carriage has a peculiar apparatus, which we shall now describe. In front of it, through the whole extent to the right hand as well as the left, a slender iron rod, d^5, runs horizontally along, in a line somewhat higher than the middle of the copping portion of the spindles, and is supported by several props, such as e^5. Upon each end of the two rods, d^5, there is an arm, g^5; and betwixt these arms an iron wire, called the copping wire, f^5, is stretched, parallel with the rod d^5. For the support of this wire, there are several slender bent arms h^5 extended from the rod d^5 at several points betwixt the straight arms g^5. The rod d^5 has, besides, a wooden handle at the place opposite to where the spinner stands, by which it can be readily grasped. This movement is applied at the left division of the machine, and it is communicated to the right by an apparatus which resembles a crane's bill. The two arms, g^5, in the middle of the machine, project over the rods d^5, and are connected by hinges with two vertical rods j^5, which hang together downwards in like manner with two arms i^5, proceeding from a horizontal axis k^5.

By means of that apparatus the yarn is wound upon the spindles in the following manner. As long as the stretching and twisting go on, the threads form an obtuse angle with the spindles, and thereby slide continually over their smooth rounded tips during their revolution, without the possibility of coiling upon them. When, however, the spinning process is completed, the spinner seizes the carriage with his left hand and pushes it back towards the roller beam, while with his right hand he turns round the handle of the rim or fly wheel, and consequently the spindles. At the same time, by means of the handle upon the rod d^5, he moves the copping-wire f^5, so that it presses down all the threads at once, and places them in a direction nearly perpendicular to the spindles; as shown by the dotted line y^5. That this movement of the copping wire, however, may take place without injury to the yarn, it is necessary to turn the rim beforehand a little in the opposite direction, so that the threads may get uncoiled from the upper part of the spindles, and become slack; an operation called in technical language the *backing off*. The range upon which the threads should be wound, in order to form a conical cop upon the spindle, is hit by depressing the copping wire to various angles, nicely graduated by an experienced eye. This faller wire alone is not, however, sufficient for the purpose of winding-on a seemly cop, as there are always some loose threads which it cannot reach without breaking others.

Another wire called the *counter-faller*, l^5, must be applied under the threads. It may be raised to an elevation limited by the angular piece p^5; and is counterpoised by a very light weight m^5, applied through the bent lever n^5, which turns upon the fulcrum o^5. This wire, which applies but a gentle pressure, gives tension to all the threads, and brings them regularly into the height and range of the faller f^5. This wire must be raised once more, whenever the carriage approaches the roller beam. At this instant a new stretch commences; the rollers begin again to revolve, and the carriage resumes its former course. These motions are performed by the automatic machinery.

There is a little eccentric pulley mechanism for moving the guide beam to and fro with the soft yarns, as they enter between the back rollers. On the right hand end of the back roller shaft, a worm screw is formed which works into the oblique teeth of a pinion attached to the end of the guide beam, in which there is a series of holes for the passage of the threads, two threads being assigned to each fluted roller. In the flat disc of the pinion, an eccentric pin stands up which takes into the jointed lever upon the end of the guide beam, and, as it revolves, pushes that beam alternately to the left and the right by a space equal to its eccentricity. This motion is exceedingly slow, since for each revolution of the back roller, the pinion advances only by one tooth out of the 33 which are cut in its circumference.

After counting the number of teeth in the different wheels and pinions of the mule, or measuring their relative diameters, it is easy to compute the extension and twist of the yarns; and when the last fineness is given to ascertain their marketable value. Let the ratio of speed between the three drawing rollers be $1 : 1\frac{3}{22} : 7\frac{1}{2}$; and the diameter of the back and middle roller three quarters of an inch: that of the front roller one inch; in which case the drawing is thereby increased $1\frac{1}{3}$ times, and $7\frac{1}{2} \times 1\frac{1}{3} = 10$. If the rovings in the creel bobbins have been No. 4, the yarn, after passing through the rollers, will be No. 40. By altering the change pinion (not visible in this view) the fineness may be changed within certain limits, by altering the relative speed of the rollers. For one revolution of the great rim or fly wheel of the mule, the front roller makes about 6 tenths of a turn, and delivers therefore 22·6 lines or 12ths of an inch of yarn, which, in consequence of the tenfold draught through the rollers, corresponds to 2·26 lines of roving fed in at the back rollers. The spindles or their whorls make about 66 revolutions for one turn of the rim. The pulleys or grooved wheels on which the carriage runs, perform 0·107 part of a turn while the rim makes one revolution, and move the carriage 24·1 lines upon its rails, the wheels being 6 inches in diameter.

The 22·6 lines of soft yarn delivered by the front rollers will be stretched $1\frac{1}{2}$ lines by the carriage advancing 24·1 lines in the same time. Let the length of the railway, or of each stretch, be 5 feet, the carriage will complete its course after 30 revolutions of the rim wheel, and the 5 feet length of yarn (of which $56\frac{1}{2}$ inches issue from the drawing rollers, and $3\frac{1}{2}$ inches proceed from the stretching) is, by the simultaneous whirling of the spindles, twisted 1980 times, being at the rate of 33 twists for every inch. The second twist, which the threads receive after the carriage has come to repose, is regulated according to the quality of the cotton wool, and the purpose for which the yarn is spun. For warp yarn of No. 40 or 50, for example, 6 or 8 turns of the rim wheel, that is, from 396 to 528 whirls of the spindles for the whole stretch, therefore from 7 to 9 twists per inch will be sufficient. The finished yarn thus receives from 40 to 42 twists per inch.

One spinner attends to two mules, which face each other, so that he needs merely turn round in the spot where he stands, to find himself in the proper position for the other mule. For this reason the rim wheel and handle, by which he operates, are not

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placed in the middle of the length of the machine, but about two fifths of the spindles are to the right hand and three fifths to the left; the rim wheel being towards his right hand. The carriage of the one mule is in the act of going out and spinning, while that of the other is finishing its twist, and being put up by the spinner.

The quantity of yarn manufactured by a mule in a given time, depends directly upon the number of the spindles, and upon the time taken to complete every stretch of the carriage. Many circumstances have an indirect influence upon that quantity, and particularly the degree of skill possessed by the spinner. The better the machine, the steadier and softer all its parts revolve, the better and more abundant is its production. When the toothed wheels do not work truly into their pinions, when the spindles shake in their bushes, or are not accurately made, many threads break, and the work is much injured and retarded. The better the staple of the cotton wool, and the more careful has been its preparation in the carding, drawing, and roving processes, the more easy and excellent the spinning will become: warmth, dryness, cold, and moisture have great influence on the ductility, so to speak, of cotton. A temperature of 65° F., with an atmosphere not too arid, is found most suitable to the operations of a spinning mill. The finer the yarn, the slower is the spinning. For numbers from 20 to 36, from 2 to 3 stretches of warp may be made in a minute, and nearly 3 stretches of weft; for numbers above 50 up to 100, about 2 stretches; and for numbers from 100 to 150, one stretch in the minute. Still finer yarns are spun more slowly, which is not wonderful, since, in the fine spinning mills of England, the mules usually contain upwards of 500 spindles each, in order that one operative may manage a great number of them, and thereby earn such high wages as shall fully remunerate his assiduity and skill.

In spinning fine numbers, the second speed is given before the carriage is run out to the end of its railway; during which course of about six inches, it is made to move very slowly. This is called the second stretch, and is of use in making the yarn level by drawing down the thicker parts of it, which take on the twist less readily than the thinner, and therefore remain softer and more extensible. The stretch may therefore be divided into three stages. The carriage first moves steadily out for about 4 feet, while the drawing rollers and spindles are in full play; now the rollers stop, but the spindles go on whirling with accelerated speed, and the carriage advances slowly about 6 inches more; then it also comes to rest, while the spindles continue to revolve for a little longer, to give the final degree of twist. The acceleration of the spindles in the second and third stages, which has no other object but to save time, is effected by a mechanism called the *counter*, which shifts the driving band, at the proper time, upon the loose pulley, and, moreover, a second band, which had, till now, lain upon its loose pulley, upon a small driving pulley of the rim-shaft. At length, both bands are shifted upon their loose pulleys, and the mule comes to a state of quiescence.

The SELF-ACTOR MULE, or the IRON MAN, as it has been called in Lancashire, is an invention to which the combinations among the operative spinners obliged the masters to have recourse. It now spins good yarn up to 40s with great uniformity and promptitude, and requires only juvenile hands to conduct it, to piece the broken yarns, to replace the bobbins of rovings in the creel, and to remove the finished cops from the spindles.

The self-acting mules were first constructed, I believe, by Messrs. Eaton, formerly of Manchester, who mounted ten or twelve of them in that town, four at Wiln, in Derbyshire, and a few in France. From their great complexity and small productiveness, the whole were soon relinquished, except those at Wiln. M. de Jong obtained two patents for self-acting mules, and put twelve of them in operation in a mill at Warrington, of which he was part proprietor; but with an unsuccessful result. I saw the *débris* of one of M. de Jong's self-actors in the factory of M. Nicholas Schlumberger, at Guebwiller, in Alsace, where the machine had been worked for three months, without advantage, under the care of the inventor, who is a native of that valley.

The first approximation to a successful accomplishment of the objects in view, was an invention of a self-acting mule, by Mr. Roberts, of Manchester; one of the principal points of which was the mode of governing the winding-on of the yarn into the form of a cop; the entire novelty and great ingenuity of which invention was universally admitted, and proved the main step to the final accomplishment of what had so long been a desideratum. For that invention a patent was obtained in 1825, and several headstocks upon the principle were made, which are still working successfully.

In 1830, Mr. Roberts obtained a patent for the invention of certain improvements; and by a combination of both his inventions, he produced a self-acting mule, which is generally admitted to have exceeded the most sanguine expectations, and which has been extensively adopted. There are probably, at present, upwards of half a million of spindles of Messrs. Sharp, Roberts, and Co.'s construction, at work in the United Kingdom, and giving great satisfaction to their possessors. The advantages of these self-actors are the following:—

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The saving of a spinner's wages to each pair of mules, piecers only being required, as one overlooker is sufficient to manage six or eight pairs of mules. The production of a greater quantity of yarn, in the ratio of from 15 to 20 per cent. The yarn possesses a more uniform degree of twist, and is not liable to be strained during the spinning, or in winding-on, to form the cop; consequently, fewer threads are broken in these processes, and the yarn, from having fewer piecings, is more regular.

The cops are made firmer, of better shape, and with undeviating uniformity; and, from being more regularly and firmly wound, contain from one third to one half more yarn than cops of equal bulk wound by hand; they are consequently less liable to injury in packing or in carriage, and the expense of packages and freight (when charged by measurement) is considerably reduced.

From the cops being more regularly and firmly wound, combined with their superior formation, the yarn intended for warps less frequently breaks in winding or reeling, consequently there is a considerable saving of waste in those processes.

Secondly, the advantages connected with weaving.

The cops being more regularly and firmly wound, the yarn, when used as weft, seldom breaks in weaving; and as the cops also contain a greater quantity of weft, there are fewer bottoms, consequently there is a very material saving of waste in the process of weaving.

From those combined circumstances, the quality of the cloth is improved, by being more free from defects caused by the breakage of the warp or weft, as well as the selvages being more regular.

The looms can also be worked at greater speed; and, from there being fewer stoppages, a greater quantity of cloth may be produced.

That the advantages thus enumerated, as derivable from the use of self-acting mules, have not been overrated, but, in many instances, have been considerably exceeded, I have, by extensive personal inquiry and observation, had ample opportunity of ascertaining.

Statement of the quantity of yarn produced on Messrs. Sharp, Roberts, and Co.'s self-acting mules, in twelve working hours, including the usual stoppages connected with spinning, estimated on the average of upwards of twenty mills:—

No. of Yarn.	No. of Twist.	No. of Weft.
16 - -	4½ hanks - -	4⅞ hanks per spindle.
24 - -	4¼ — - -	4⅝ —
32 - -	4 — - -	4⅜ —
40 - -	3¾ — - -	4⅛ —

Of the intermediate numbers the quantities are proportionate.

Results of trials made by Messrs. Sharp, Roberts, and Co., at various mills, to ascertain the comparative power required to work self-acting mules, in reference to hand-mules, during the spinning, up to the period of backing off.

Particulars of the trials referred to, and their results:—

At what Mill, and the Description of Mule.	No. and kind of Yarn.	Diameter of Pulley or Rim Wheel.	Revolutions of Pulley or Rim Wheel.	Required Force for Motion.	Total Force Employed in Spinning.
Messrs. Birley and Kirk.	*Weft.*	*Ins.*		*lbs.*	*lbs.*
Self-acting mule, 360 sps. - -	30 to 34	12	58	30	5463
* Hand-mule, 180 sps. - - -	ditto	15	36	26	3669 ×2=7338
Messrs. Leech and Vandrey.	*Twist.*				
† Self-acting mule, 324 sps. -	36	12	70	36	7912
Hand-mules, 324 sps. - - -	36	29	58	16½	7273
Messrs. Duckworth & Co.	*Twist.*				
Self-acting mule, 324 sps. - -	40	12	62	33	6421
Hand-mule, 324 sps. - - -	40	47	36	15½	6646

The mode adopted to make the trials was as follows, viz.:

A force, indicated by weight in pounds, was applied to the strap working upon the driving-pulley of the respective mules, sufficient to maintain the motion of the mule whilst spinning, which weight, being multiplied by the length of strap delivered by each revolution of the pulley, and again by the number of revolutions made by the pulley whilst spinning, gave the total force in pounds, applied to the respective mules whilst spinning; for instance, suppose a mule to be driven by a pulley 12 inches diameter (3·14 feet in circumference), such pulley making 58 revolutions during the spinning as above, and that it required a force equal to 30 lbs. weight to maintain the motion of the mule, then 30 lbs. × 3·14 feet circumference of pulley × 58 revolutions in spinning = 5,463 lbs. of force employed during the spinning, to the period of backing off.

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* The trial was disadvantageous for the hand-mules, being two for 360 spindles.

† The trial was disadvantageous for the self-acting mules, being driven by a very short and light vertical strap, the hand-mule having a long horizontal strap.

Mr. James Smith, of Deanstone cotton works in Scotland, obtained a patent for the invention of a *self-actor*, in February, 1834. He does not perform the backing-off by reversing the rotation of the spindle, as in common mules, or as in Mr. Roberts', but by elevating the counterfaller wire, which, being below the ends of the yarn or thread, along the whole extent of the carriage, thereby pulls off or strips the spiral coils at the point of the spindle, instead of unwinding them, as of old. This movement he considers to be of great importance towards simplifying the machinery for rendering the mule self-acting; and the particular way in which he brings the stripper into action is no doubt ingenious, but it has been supposed by many to strain the yarn. He claims as his invention the application and adaptation of a mangle wheel or mangle rack to the mule, for effecting certain successive movements, either separately or in conjunction; he claims that arrangement of the carriages of a pair of mules, by which the stretch is caused to take place over part of the same ground by both carriages, and thereby the space required for the working of the pair of mules is greatly diminished; and he claims the application of a weight, spring, or friction, for balancing the tension of the ends of the threads.

A patent was granted, in April, 1835, to Mr. Joseph Whitworth, engineer in Manchester, for some ingenious modifications of the mechanism of the mule, subservient to automatic purposes. His machinery is designed, first, to traverse the carriage in and out, by means of screws or worm-shafts, which are placed so as to keep the carriage parallel to the drawing rollers, and prevent the necessity of squaring bands, hitherto universally employed: secondly, his invention consists in an improved manner of working the drums of a self-acting mule by gear; thirdly, in the means of effecting the backing off; fourthly, in the mechanism for working the faller-wire in building the cops; and fifthly, in the apparatus for effecting the winding of the yarns upon the spindles. As regards the throstles and doubling frames, his improvements apply, first, to the peculiar method of constructing and adapting the flyers and spindles, and producing the drag; and, secondly, to the arrangement of the other parts of the doubling machinery.

See Lace-Making, Singeing, Textile Fabric, Thread Manufacture, and Weaving.

We extract the following from the Circular of Hermann Cox and Co., dated 19th July, 1852.

Export from 1st January to 5th May, as follows:

	1852.	1851.
Exportations of Yarn - - -	50,399,189 lbs.	42,630,812 lbs.
„ Manufactured Goods -	509,350,295 yds.	493,915,720 yds.

consequently a considerable surplus on both over last year; the official return till 5th June, just out, again shows an increase, viz.:

	1852.	1851.
Exportations of Yarn - - -	63,418,111 lbs.	54,634,370 lbs.
„ Manufactured Goods -	649,341,927 yds.	630,581,674 yds.

The following is a return of exports from Hull, from 1st January till 30th June

	Twist.	Other Yarn.	Manufactured Cotton Goods.	Raw Cotton.
1852. -	33,182 bales.	12,115 bales.	11,536 bales.	65,186 bales.
1851. -	31,601 „	9,634 „	11,347 „	33,054 „

AMERICA.

	1851.	1852.
Stock 1st September in the Ports - -	148,000 bales.	128,000 bales.
Receipts till 22d June - - -	2,250,000 „	2,936,000 „
	2,398,000 „	3,064,000 „
Shipments to Europe till 22d June -	1,758,000 „	2,263,000 „
	640,000 „	801,000 „
Deduct Stock 22d June - - -	304,000 „	201,000 „
American Consumption for 1851 - -	336,000 bales.	600,000 bales.

Last year the American spinners took from the above-named last date till 1st Sept., 137,000 bales.

FRANCE.

Notwithstanding 96,348 bales larger supply, the stock is still 12,293 bales smaller than last year.

	1851.				
	Stock, 1st January.	Imports to 1st July.	Total.	Deduct Stock, 1st July.	Leaves for Consumption.
Havre -	39,825	210,140	249,965	78,377	171,588 bales.
Marseilles -	15,095	26,124	41,219	17,479	23,740 „
	54,920	236,264	291,184	95,856	195,328 bales.
or 7,512 bales per week.					
			1852.		
Havre -	22,767	297,514	320,281	75,271	245,010 bales.
Marseilles -	7,661	35,098	42,759	8,292	34,467 „
	30,428	332,612	363,040	83,563	279,477 bales.

or 10,749 bales per week this year against 7,512 bales in the same period last year, or 7,326 bales average of 1851.

REMAINING CONTINENT.

We find the consumption of the first six months of 1851 and 1852 to be as follows:

	1851.				
	Stock, 1st January.	Direct Imports.	Total.	Deduct Stock, 1st July.	Leaves for Consumption.
Hamburg - - - -	6,300	33,730	40,030	6,730	33,300 bales.
Bremen - - - - -	89	21,191	21,280	12,133	9,147 „
Petersburg and Sweden -	5,575	7,000	12,575	4,000	8,575 „
Amsterdam - - - -	1,362	4,888	6,250	2,698	3,552 „
Rotterdam - - - -	467	1,912	2,379	1,333	1,046 „
Antwerp - - - - -	4,578	25,173	29,751	8,500	21,251 „
Trieste - - - - -	22,596	79,582	102,178	49,004	53,174 „
Spain, Portugal, and Italy -	6,000	68,000	74,000	8,000	66,000 „
	46,967	241,476	288,443	92,398	196,045 bales.
			Add Export from England	-	95,300 „
			Total - - - -	-	291,345 bales.

or 11,205 bales per week.

1852.					
	Stock, 1st January.	Direct Imports.	Total.	Deduct Stock 1st July.	Leaves for Consumption.
Hamburg - - - - -	5,900	65,929	71,829	17,990	53,839 bales.
Bremen - - - - -	1,664	16.303	17,967	3,304	14 663 „
Petersburg and Sweden -	2.000	23,000	25,000	5,000	20,000 „
Amsterdam - - -	2,101	6,890	8.991	4,157	4,834 „
Rotterdam - - -	928	11,581	12.509	8,350	4,159 „
Antwerp - - - - -	1,196	54.282	55,478	22,000	33,478 „
Trieste - - - - -	25,914	72,392	98,306	29,857	68,449 „
Spain, Portugal, and Italy -	4,219	97,000	101,219	9,000	92,219 „
		347,377		99,658	291,641 bales.
			Export from England -		147,000 „
			Total - - -		438,641 bales.

or 16,870 bales per week, against 11,205 bales in the first half of last year, or against 11,664 bales average of the whole period of 1851.

The total consumption of all countries according to the preceding statements is as follows:

England - - - - -	39,683 bales, against	29,851 bales, 1851.
America - - - - -	11,538 „	6,461 „
France - - - - -	10,749 „	7,512 „
Remaining Continent - -	16,870 „	11,205 „
	78,840	55,029 bales per week.

To which we, however, consider it advisable to add, that this increase in the consumption for the first half year (viz., 23,811 bales per week) should not be taken as any criterion against the consumption of the same period last year, when it was so much restricted through the drooping state of prices, and when spinners were induced to use up their whole stocks. We affirm therefore that this increase of consumption should only be considered in comparison with the average consumption of the whole of last year, viz.:

In England - - - - - - -	31,973 bales in 1851.
America - - - - - - -	9,479 „
France - - - - - - -	7,326 „
Remaining Continent - - - - -	11,664 „
	60,442 bales per week.
Against - -	78,840 „ this year.

We have thus far represented the consumption—the extraordinary increase of the same in all countries, without exception, proves how cheap food, with peace, tends to enlarge consumption; and it remains therefore only to be hoped that the favorable prospects for the ensuing crop be not blighted. It is clearly evident that present prices do not affect the consumption; for the planters they are sufficiently remunerative to induce an extension of the culture, and so provide for the world such stocks as would prevent any ill effect arising from a future small or bad crop.

It shall now be our endeavor to point out the position of stocks in all Europe on the 31st December this year, supposing the consumption to continue at its present rate:

The American crop - - - - - - -	3,000,000 bales.
Of which were received by the last list of 22d June -	2,936,329 „
Remain to receive - - - - - - -	63,671 „
Stocks in the ports and on shipboard 22d June - -	201,773 „
	265,444
The average stock left in the ports during the last six years was about 150,000 bales, but we will take for this year only - - - - - - - - -	100,000 „
Would leave for all Europe - - - - -	165,444 „

Suppose American spinners take nothing more from 22d June till 1st September.

Brought forward - -		165,444 bales.
From America, floating to England - - - - -		150,000 „
„ „ „ to other countries - - -		100,000 „
„ India „ to England - - - - -		100,000 „
to receive from other countries till 31st December, equal to last year.		
England - from Egypt, Brazils, and Sundries -	83,000	
France - „ Egypt, Brazils, and Smyrna -	26,000	
Trieste, and other Ports, „ Egypt, Brazils, and Smyrna -	40,000	
		149,000 „
Total supply for Europe - - - - -		664,444 „
Add stocks in all European ports on 1st July - -		900,421 „
Total -		1,564,865 „
Quantity of American, next crop, to be received in England		150,000 „
Ditto in Continental ports - - - - - - -		75,000 „
		1,789,685 bales.

Therefore, if the present consumption of Europe were to continue to the end of the year, the stock would be only 39,084 in all European ports, not enough for one week

Table of Imaginary Stocks in Great Britain on 31st December, 1852.

The American crop - - - - - - -	3,000,000 bales.
Of which were received by the last list of 22d June - -	2,936,329 „
Remain to receive - - - - - - -	63,671 „
Stocks in the ports and on shipboard 22d June - -	201,773 „
	265,444 „
The average stock left in the ports during the last six years was about 150,000 bales, but we will take for this year only	100,000
	165,444 „
We will suppose American spinners to take nothing more till 1st September, and supposing the 32 ships loading for France, and 125 for other ports take only - -	65,444 „
Would leave for Great Britain - - - - -	100,000 „
As the stocks in the interior markets are only one third of those of last year, shipments after August must fall very short; but supposing England to receive from 1st September till 31st December - - - - - - -	150,000 „
Now floating to England - - - - - -	150,000 „
From India we will suppose - - - - - -	100,000 „
From Brazils, Egypt, &c., like last year in the same period -	83,000 „
Total to receive -	583,000 „
Add stock 1st July in Great Britain - - - - -	717,200 „
	1,300,200 bales.

Export

until 1st July last year was 95,300 bales, for the same period this year 147,000 bales. We have shown that the Continental stocks, notwithstanding so much larger receipts, are only near on a par with those of last year; this leads us to suppose that our market must later assist those by large exports, but we will take such only equal to last year, viz. - - - - - - -	121,000 bales.
Leaves - - - - - -	1,179,200 „
Whereas the present rate of consumption requires till 31st Dec. -	1,031,758 bales.

This would leave us a stock at this year's end of all descriptions of 147,442 bales only, not sufficient for the consumption of four weeks; supposing, however, the consumption to fall to only 33,000 bales per week, the remaining stock would be only 321,000 bales, against 494,000 bales at the end of last year.

IMPORT AND STOCK OF COTTON IN LIVERPOOL—31st July, 1852.

Description.	Import in July.	Delivery.				Estimated Stock.		Prices.		Import.			Total Import, 1852.
		In July, 1852.	In July, 1851.	7 Months, 1852.	7 Months, 1851.	31st July, 1852.	31st July, 1851.	31st July, 1852.	31st July, 1851.	Whence.	7 Months, 1852.	7 Months, 1851.	
Sea Island	134,192	148,942	157,133	1,036,596	767,042	513,200	540,000	15 *a* 30	8 *a* 24	Savannah	92,886	112,442	119,674
Stained do.								5½ 14	4½ 9½	Charleston	160,025	135,266	165,303
Upland								4½ 6½	3½ 6	Northern Ports	181,756	133,930	167,120
Mobile								4½ 6¼	3½ 5½	New Orleans, &c.	879,009	664,164	886,612
New Orleans								4¼ 7½	3¼ 7¾	Pernambuco	41,750	27,086	52,486
Pernambuco	9,042	5,142	6,089	40,170	32,316	13,900	14,200	6½ 7¾	6 7½	Bahia	18,789	11,512	26,614
Aracati and Ceara								6½ 7½	5¾ 7	Maranham	20,279	23,161	29,570
Bahia and Muceio	6,345	2,745	2,528	20,019	18,722	8,800	10,700	6½ 7	5¾ 6¼	Peruvian	10	47	47
Maranham	5,281	3,281	3,204	26,509	20,531	20,900	33,900	6¼ 7½	5¼ 7	Demerara	677	368	473
Sawginned do.								5¼ 6	4¾ 5¼	West Indies, &c,	3,971	2,199	6,829
Demerara	164	164	35	777	258	50	150	5½ 12	5½ 6¾	Egypt	93,559	45,079	62,349
West India, &c.	985	1,085	529	4,501	2,106	5,300	1,000	5½ 9	4½ 5½	Bombay	27,090	99,027	225,932
Egyptian	26,846	8,446	8,123	60,089	41,759	53,300	35,500	5½ 12	5¼ 9	Madras	- -	4,595	5,280
Surat and Madras	2,124	16,124	13,397	109,580	115,772	31,500	79,800	3 4¾	2½ 4¼	Calcutta	704	1,700	1,700
Bengal	- -	100	100	944	1,200	100	500	3¾ 4½	2½ 4½				
Total	185,729	186,029	191,138	1,299,185	999,706	645,050	715,750	- -	- -	- - -	1,520,505	1,260,576	1,749,989

The sales during the month of July amounted to 277,260 bales, of which 109,420 were taken as taken on speculation and for export, consisting of 93.510 American, 4.430 Pernambuco, 1,170 Bahia, 20 Maranham, 3,800 Egyptian, and 6,490 East India. The actual export was 15,000 American, 1,600 Brazil, and 1,500 Surat; and from 1st of January to 31st July, 106,300 American, 7,000 Brazil, 200 West India, 300 Egyptian, and 28,600 Surat, &c. Prices advanced during the month ¼*d*. per lb.

IMPORT, DELIVERY, AND STOCK OF COTTON, IN GREAT BRITAIN, FIRST SEVEN MONTHS, 1851 AND 1852.

	1851.						1852.					
	American.	Brazil.	West Indies.	Egyptian.	East India.	Total.	American.	Brazil.	West Indies.	Egyptian.	East India.	Total.
Stock, 1st January	272,710	68,650	1,510	34,870	143,380	521,120	245,810	49,520	4,310	22,910	172,050	494,600
Import, 7 months	1,097,501	61,759	3,418	45,539	148,416	1,356,633	1,363,809	80,935	5,007	95,734	46,984	1,592,469
	1,370,211	130,409	4,928	80,409	291,796	1,877,753	1,609,619	130,455	9,317	118,644	219,034	2,087,069
Taken for export	83,500	6,600	- -	300	46,900	137,300	106,850	7,000	200	300	53.950	168,300
	1,286,711	123,809	4,928	80,109	244,896	1,740,453	1,502.769	123,455	9,117	118,344	165,084	1,918,769
Estimated stock, 31st July	567,000	58,800	2,000	37,800	136,550	802,150	540,000	43,600	4,000	54,700	72,050	714.350
Taken for consumption	719,711	65,009	2,928	42,309	108,346	938.303	962,769	79,855	5,117	63,644	93,034	1,204,419
Or per week	23,727	2,143	96	1,395	3,572	30,933	31,739	2,633	169	2,098	3,067	39,706
Total import, 1851	1,397,112	108,670	8,476	63,833	326,474	1,904,565						
Total export, 1851	151,950	12,000	200	900	103,450	268,500						
Weekly consumption, 1851	24,463	2,227	105	1,440	3,738	31,973						
Import last 5 months 1851	299,611	46,911	5,058	18,294	178,058	547,932						

COTTON REPORT OF HERMANN COX & CO., IN LIVERPOOL AND LONDON, DATED AUGUST 6th, 1852.

Sales.			Sorts.	Present Price.						Supply.			Export.		Consumption.		On Hand.		
This Week.	From Jan. 1 to Aug. 6.									This Week.	From Jan. 1. to Aug. 6.		From Jan. 1. to Aug. 6.		From Liverpool alone, from Jan. 1 to Aug. 6.		On August 6.		Jan. 1.
	1852.	1851.		Ord.	Good Ord.	Mid.	Good Mid.	Fair.	Good Fair.		1852.	1851.	1852.	1851.	1852.	1851.	1852.	1851.	1852.
250	20,210	17,260	Sea Island	15	16 1-2	18	19	20	21	11,772	487,743	432,979	106,788	57,566	948,770	715,600	534,000	524,800	236,120
10,690	404,940	329,650	Georgia - -	5	5 1-8	5 3-8	5 5-8	6	6 1-4										
6,010	290,039	146,270	Mobile - -	5	5 3-16	5 7-16	5 11-16	6	6 1-4	32,743	865,702	638,578							
25,300	727,240	389,060	New Orleans -	5 1-8	5 1-4	5 1-2	5 3-4	6 3-8	7										
2,300	55,770	35,830	Pernam. &c. -	6 1-2	6 5-8	6 3-4	6 7-8	7	7 1-4	1,503	42,541	28,078	7,266	5,211	144,400	112,140	42,890	55,350	12,320
420	25,520	20,720	Bahia & Maccio	6 1-4	6 1-2	6 5-8	6 3-4	7	7 1-8	2,151	18,775	11,435							10,030
1,820	27,580	26,130	Maranham -	6 1-4	6 1-2	6 5-8	6 3-4	6 7-8	7	- -	20,217	23,161							27,130
5,980	87,740	47,950	Egyptische -	5 3-4	6	6 1-2	6 3-4	7	7 1-2	7,117	100,516	46,676							19,830
3,580	169,930	133,910	Surat - -	- -	- -	4 1-8	4 1-4	4 3-8	4 1-2	- -	27,099	102,763	28,907	21,269	84,040	94,700	56,860	35,260	113,990
- -	1,770	5,690	Madras - -	- -	- -	4	4 1-8	4 1-4	4 3-8								29,130	76,650	340
40	1,300	1,120	Bengal - -	3 1-2	3 5-8	3 3-4	3 7-8	4	4 1-2	- -	704	1,700			5,280	3,170	3,350	1,220	3,970
670	5,240	3,380	Diverso - -	- -	- -	- -	- -	- -	- -	34	4,869	3,386							
57,060	1,817,270	1,156,970		- -	- -	- -	- -	- -	- -	55,320	1,568,157	1,288,756	142,961	84,046	1,182,490	925,610	666,230	693,280	423,730
													Weekly Average		38,145	29,859			

OFFICIAL LIST FROM AMERICA.

NEW YORK, JULY 14, 1852.

	Exported.	In Vessels to					On Hand.
		England.	France.	North Europe.	Overland.	Total.	
1852	2,972,024	1,588,637	414,479	164,383	170,370	2,337,869	155,189
1851	2,286,977	1,301,747	290,597	116,047	128,782	1,837,173	235,549
	685,047	286,890	123,882	48,336	41,588	500,696	80,360

NEW YORK, JULY 21, 1852.

	Exported.	In Vessels to					On Hand.
		England.	France.	North Europe.	Overland.	Total.	
1852	2,977,884	1,607,416	417,555	164,383	174,476	2,363,830	127,834
1851	2,296,126	1,322,340	290,683	117,193	133,032	1,863,248	204,613
	681,758	285,076	126,872	47,190	41,444	500,582	76,779

IMPORT OF COTTON WOOL INTO LIVERPOOL IN THE YEAR 1851, AND FOR THE EIGHT PREVIOUS YEARS, WITH THE GENERAL IMPORT INTO GREAT BRITAIN FOR THE LAST TEN YEARS, AND THE STOCKS OF THE DIFFERENT DESCRIPTIONS REMAINING ON HAND AT THE CLOSE OF 1850 AND 1851.

	American.	Brazil.	Demerara and Berbice.	West India Islands.	East Indies.	Egypt, &c.	Monthly Import. 1851.	Monthly Import. 1850.
January -	75,900	6,766	—	435	11,650	955	95,706	159,624
February -	59,989	4,940	—	63	18,968	2,552	86,512	108,042
March - -	183,639	11,738	—	337	27,532	6,048	229,294	78,132
April - -	113,147	6,824	—	255	13,734	7,081	141,041	224,179
May - -	259,853	12,546	—	151	17,990	6,257	296,797	155,345
June - -	185,127	11,582	—	534	5,178	14,821	217,242	115,199
July - -	166,997	7,321	—	645	10,297	7,631	192,891	171,666
August -	91,398	7,912	—	238	29,363	6,156	135,067	151,796
September -	35,302	8,718	—	294	21,106	2,172	67,592	114,814
October -	31,807	13,910	—	191	39,603	5,173	90,684	94,363
November -	46,733	7,139	—	732	28,972	3,895	87,471	75,617
December -	87,657	9,248	—	27	8,546	2,726	108,204	124,257
Totals 1851 -	1,337,549	108,644	—	3,902	232,939	65,467	1,748,501	1,573,034
Totals 1850 -	1,125,875	170,155	—	4,355	192,535	80,114	Increase of Import, 1851, 175,467	

Imported into Liverpool	1843.	1844.	1845.	1846.	1847.	1848.	1849.
From United States . .	1,286,384	1,158,845	1,373,905	933,921	829,291	1,296 903	1,382,590
Brazil	98,586	111,509	110,843	83,950	109,820	100,142	163,530
Demerara and Berbice .	- -	- -	- -	- -	- -	- -	- -
West Indies . . .	15,038	14,831	6,754	9,219	5,608	6,087	7,970
East Indies . . .	110,868	142,817	82,539	46,432	122,049	136,012	106,960
Egypt, &c. . . .	48,953	61,326	79,154	59,614	20,732	27,820	71,320
	1,559,829	1,489,328	1,653,195	1,134,136	1,087,500	1,566,964	1,732,300

Imported into Great Britain.	1845.	1846.	1847.	1848.	1849.	1850.	1851.
From United States . .	1,499,683	992,497	872,700	1,374,342	1,477,220	1,182,202	1,395,887
Brazil	110,851	83,950	110,385	100,185	163,530	170,155	108,644
Demerara and Berbice West Indies . .	9,174	13,530	6,660	7,835	9,460	4,666	4,799
East Indies . . .	158,057	91,665	222,802	227,572	182,010	309,109	326,437
Egypt, &c. . . .	82,063	60,668	20,732	29,033	72 720	80,254	67,172
	1,859,328	1,242,310	1,233,279	1,738,967	1,904,940	1,746,386	1,902,939

STOCK IN LIVERPOOL.

31st Dec.	Sea Island.	Orleans	Bowed	Mobile	Total Amer.	Pernm.	Bahia.	Maranham.	Dem.	W. In. &c.	Egyptian.	Surat.	Bengal	Total.
1851	2,330	121,560	60,480	51,750	236,120	12,320	10,030	27,130	140	3,830	19,830	113,990	340	423,730
1850	4,296	130,928	90,140	35,870	261,234	19,435	17,909	31,269	40	778	32,267	89,577	2,370	454,879
1849	5,410	156,200	65,301	51,421	278,332	29,815	26,998	38,359	89	1,435	35,318	57,829	- -	468,175
1848	6,180	126,160	50,840	52,030	235,210	22,270	10,480	35,660	60	1,570	14,450	72,470	1,170	393,340

GENERAL IMPORT, CONSUMPTION AND STOCK *IN* GREAT BRITAIN—FROM 1841 TO 1851, INCLUSIVE.

	Liverpool.	London.	Glasgow, &c.	Total Import.	Total Con.	Average weekly con.	Total Stock.	Equal to week's Con.
1842	1,254,108	75,260	67,863	1,397,241	1,192,220	22,927	564,534	24
1843	1,559,829	61,247	125,191	1,746,265	1,403,477	26,988	785,952	29
1844	1,489,328	77,778	114,027	1,681,133	1.414,565	27,203	903,060	33
1845	1,653,195	68,264	138,369	1,859,828	1.568,718	30,168	1,060,270	35
1846	1,133,036	36,167	73,107	1,242,310	1,562,590	30,049	545,790	18
1847	1,087,500	81,084	64,695	1,233,279	1,105,280	21,255	451,939	21
1848	1,566,964	69,911	102,392	1,738,967	1.510.656	29,045	496,050	17
1849	1,732,300	61,490	91,000	1,904.940	1,590,330	30,200	559,410	18
1850	1,573,034	90,331	82,971	1,746,386	1,502,063	28,884	522,029	18
1851	1,748,501	65,780	88,658	1,902,939	1,662,001	31,962	495,104	15½

GENERAL IMPORT, EXPORT, QUANTITY TAKEN OUT OF THE PORTS FOR CONSUMPTION, AND STOCK, AT THE CLOSE OF 1851, 1850, AND 1849.

	IMPORT.					EXPORT.					ANNUAL CONSUMPTION.					WEEKLY CONSUMPTION.					STOCK.				
	Liverpool.	London.	Glasgow.	Other Ports.	Total.	Liverpool.	London.	Glasgow.	Other Ports.	Total.	Liverp.	London.	Glasgow.	Other Ports.	Total.	Liverpool.	London.	Glasgow.	Other Ports.	Total.	Liverpool.	London.	Glasgow.	Other Ports.	Total.
America -	1,337,549	1,670	43,368	13,300	1,395,887	153,817	1,450	429	1,000	156,696	1,184,992	100	80,145	23,920	1,289,157	22,789	2	1,541	460	24,792	236,120	150	7,544	2,500	246,314
Brazil -	108,644	- -	- -	- -	108,644	8,944	- -	- -	- -	8,944	115,346	- -	- -	- -	115,346	2,219	-	- -	- -	2,219	49,480	40	- -	- -	49,520
Dem. W. I. &c	3,902	630	267	- -	4,799	180	- -	- -	- -	180	4,752	810	- -	- -	5,562	91	16	- -	-	107	3,970	210	- -	- -	4,180
East Indian	232,939	63,090	22,308	8,100	326,437	45,355	52,580	- -	2,000	99,935	147,445	5,820	10,100	11,960	175,325	2,835	112	194	240	3,371	114,330	52,630	4,094	1,000	172,054
Egyptian, &c.	65,467	390	1,055	260	67,172	940	- -	- -	- -	640	76,511	100	- -	- -	76,611	1,471	2	- -	- -	1,473	19,830	290	2,916	- -	23,036
Totals 1851	1,748,501	65,780	66,998	21,660	1,902,939	209,236	54,030	429	3,000	266,695	1,529,046	6,830	90,245	35,880	1,662,001	29,405	132	1,735	690	31,962	423,730	53,320	14,554	3,500	495,104
Totals 1850	1,573,034	90,381	59,321	23,650	1,746,386	200,999	69,688	1,905	1,600	274,192	1,386,521	10,270	89,242	16,000	1,502,063	26,664	197	1,716	307	28,884	454,879	49,730	14,850	2,590	522,029
Totals 1849	1,732,300	51,490	91,000	30,150	1,904,940	188,830	63,100	2,850	3,800	258,580	1,461,100	6,320	97,910	25,000	1,590,330	28,101	121	1,881	480	30,583	468,170	39,760	44,480	7,000	559,410

PRICES THIRTY-FIRST DECEMBER.

Years.		Ordin. to Mid.	Fair to Good Fair.	Good to Fine.	Years.		Ordin. to Mid.	Fair to Good Fair.	Good to Fine.
1851	Bowed	3¼*d.* @ 4*d.* 11-16	3*d.* @ 5⅛*d.*	5¼*d.* @ 5 *d.*	1851	Orleans.	3¾*d.* @ 4*d.* 13-16	5⅛*d.* @ 5 *d.*	5¾*d.* @ 7*d.*
1850	Ditto	6¾ — 7¾	7⅞ — 8	8⅛ — 8¼	1850	Ditto	6½ — 7⅞	8⅛ — 8⅜	8½ — 9
1849	Ditto	5½ — 6⅛	6⅜ — 6½	6⅝ — 6¾	1849	Ditto	5½ — 6¼	6¾ — 7	7½ — 8½
1848	Ditto	3⅝ — 4	4⅛ — 4¼	4½ — 4¾	1848	Ditto	3¼ — 4	4⅜ — 4¾	5¼ — 6
1847	Ditto	3⅞ — 4½	4¾ — 4⅞	5 — 5¼	1847	Ditto	3¾ — 4⅝	5 — 5¼	6 — 7
1846	Ditto	6 — 6⅞	7¼ — 7⅜	7½ — 7⅝	1846	Ditto	5¾ — 7	7¾ — 7⅞	8 — 8½
1845	Ditto	3¼ — 3⅞	4¼ — 4⅜	4½ — 4¾	1845	Ditto	3¼ — 4⅛	4⅝ — 5	5½ — 6½
1844	Ditto	3¼ — 3⅞	4¼ — 4⅜	4⅝ — 5	1844	Ditto	3 — 5	4⅝ — 5	5½ — 7
1843	Ditto	4¾ — 4⅞	5⅜ — 5½	5⅝ — 5¾	1843	Ditto	4½ — 5⅛	5½ — 5¾	6 — 7
1842	Ditto	4 — 4⅞	5¼ — 5½	5¾ — 6	1842	Ditto	4 — 5	5⅜ — 5¾	6½ — 7½

COTTON CROP OF THE UNITED STATES.

	1851.	1850.
New Orleans - - -	933,369	781,886
Alabama - - - -	451,748	350,952
Florida - - - -	181,264	181,344
Georgia - - - -	322,376	343,635
South Carolina - - -	387,075	384,265
North Carolina - - -	12,928	11,861
Virginia, &c. - - -	19,940	- -
Texas - - - -	45,820	31,263
Total crop of the U. States	2,355,540	2,096,706

Total crop of 1851, as above - -	2,355,540
Crop of last year - - - - -	2,096,706
Crop of year before - - - -	2,728,596
Increase from last year - -	258,551
Decrease from year before - -	373,329

Export to Foreign Ports.	Great Britain.	To France and the Continent.	Total.
New Orleans - -	582,373	262,268	844,641
Alabama - - -	249,897	71,880	321,777
Florida - - -	56,187	14,367	70,547
Georgia - - -	137,143	16,504	153,647
South Carolina - -	203,970	64,048	268,018
North Carolina -	- -	- -	- -
Virginia - - -	- -	- -	- -
Baltimore - -	206	- -	481
Philadelphia - -	2,691	2,691	2,691
New York - -	184,815	136,980	321,795
Boston - - -	1,002	1,450	2,852
Texas - - -	- -	2,261	2,261
Total - - -	1,418,265	570,445	1,988,710
Total last year - -	1,106,771	483,384	1,590,155
Increase - - -	311,494	87,061	398,555

The shipments from Mississippi are included in the exports from New Orleans.

CONSUMPTION.

Total crop of the United States, 1851 -		- -	2,355,257
Add stocks on hand at the commencement of the year 1st September, 1850.			
In the southern ports - - - -		91,754	
In the northern ports - - - -		76,176	
			167,930
Makes a supply of - - - - -		- -	2,523,187
Deduct the export to foreign ports - - - - -	1,988,710		
Less foreign included - -	1,077		
		1,987,633	
Stocks on hand at the close of the year 1st September, 1851.			
In the southern ports -	89,044		
In the northern ports - -	39,260		
		128,304	
Burnt at New York and Baltimore - -		3,142	
			2,119,079
Taken for home use - - - -		- -	404,108

GROWTH.

Total Crop of Bales.		Quantity consumed by, and in the hands of Manufacturers.
		Bales.
1850-51	2,355,257	404,108
1849-50	2,090,706	487,769
1848-9	2,728,596	518,039
1847-8	2,347,634	531,772
1846-7	1,778,651	427,967
1845-6	2,100,537	422,597
1844-5	2,394,503	389,006
1843-4	2,030,409	346,744
1842-3	2,378,875	325,129
1841-2	1,683,574	267,850
1840-1	1,634,945	297,288
1839-40	2,177,835	295,193
1838-9	1,360,532	276,018
1837-8	1,301,497	246,063
1836-7	1,422,930	222,540
1835-6	1,360,725	236,733
1834-5	1,254,328	216,888
1833-4	1,205,394	196,413
1832-3	1,070,438	194,412

MONTHLY IMPORT INTO LIVERPOOL IN 1851.

1851.	Georgia.	South Carolina.	Northern Ports.	New Orleans.	Total America.	Pernambuco.	Bahia.	Maranham.	Other Ports.	Total Brazil.	Demerara.	West India.	Egypt.	Bombay.	Calcutta.	Total Other Ports.	TOTAL.
January - - -	18,541	9,538	5,767	42,054	75,900	2,814	2,915	- -	- -	5,729	53	1,419	775	11,534	296	14,077	95,706
February - -	10,434	19,476	7,141	22,938	59,989	605	201	4,119	34	4,959	9	- -	2,537	18,783	239	21,568	86,516
March - - -	16,380	36,518	16,281	114,430	183,639	3,661	1,134	6,928	38	11,761	43	232	6,063	20,998	534	33,870	229,270
April - - -	15,042	4,729	27,950	65,469	113,190	3,871	- -	2,939	14	6,824	2	108	7,188	13,734	- -	21,032	141,046
May - - -	30,260	26,144	59,165	144,282	259,851	4,203	4,086	4,251	6	12,546	12	128	6,270	17,359	631	24,400	296,797
June - - -	12,295	22,598	34,041	116,193	185,127	8,106	771	2,705	38	11,620	100	395	14,880	5,178	- -	20,553	217,300
July - - -	9,490	16,231	27,352	114,924	167,997	3,942	1,225	2,154	- -	7,321	35	610	7,631	10,297	- -	18,573	193,891
August - - -	3,320	9,255	18,329	60,494	91,398	4,089	3,823	- -	- -	7,912	- -	243	6,151	29,363	- -	35,757	135,067
September - -	1,209	1,780	6,539	25,727	35,255	2,979	2,524	3,215	- -	8,718	9	286	2,172	21,106	47	23,620	67,593
October - - -	- -	2,832	5,609	23,366	31,807	11,252	2,658	- -	- -	13,910	121	70	5,173	39,603	- -	44,967	90,684
November - -	- -	3,459	10,000	33,274	46,733	5,639	1,500	- -	- -	7,139	- -	732	3,895	28,972	- -	83,599	87,471
December - -	2,703	12,109	7,243	65,602	87,657	1,457	4,597	3,194	- -	9,248	20	7	3,120	8,546	- -	11,693	108,598
Totals of 1851 -	119,674	164,699	225,417	828,753	1,338,543	52,618	25,434	29,505	130	107,687	404	4,230	65,855	231,473	1,747	303,709	1,749,939
Totals of 1850 -	129,544	182,111	240,817	573,326	1,125,798	65,396	54,544	51,175	158	171,273	388	3,809	79,213	191,392	1,188	275,990	1,573,061
Totals of 1849 -	167,751	180,838	204,915	829,293	1,382,797	60,978	53,029	49,142	296	163,445	724	7,239	71,323	106,457	509	186,252	1,732,494

GENERAL IMPORT OF COTTON WOOL INTO GREAT BRITAIN,

From 1834 to 1851, inclusive, with the Stock at the close of each Year, and the Quantity taken for Export and Home Consumption.

	1834.	1835.	1836.	1837.	1838.	1839.	1840.	1841.	1842.	1843.	1844.	1845.	1846.	1847.	1848.	1849.	1850.	1851.
American -	731,456	763,329	764,640	846,268	1,124,180	813,170	1,236,750	902,100	1,018,880	1,398,490	1,247,350	1,501,570	991,460	873,960	1,374,260	1,477,530	1,182,970	1,396,946
Brazil - - -	103,528	143,580	147,960	116,257	137,480	97,340	86,350	93,790	85,570	98,400	112,450	112,060	84,200	110,630	102,140	163,440	171,310	107,687
East India - -	88,122	118,611	219,240	145,107	108,780	132,260	216,870	273,950	255,010	181,800	238,090	155,040	94,480	221,960	227,570	182,050	309,220	326,782
West India - -	25,546	65,287	68,990	65,776	60,260	69,080	60,400	72,530	38,200	65,900	84,970	89,400	73,830	27,450	34,740	82,170	84,600	73,100
Total, Bags, &c. -	948,652	1,090,807	1,200,830	1,173,408	1,430,700	1,111,850	1,600,370	1 342,370	1,397,660	1,744,590	1,682,860	1,858,070	1,243,970	1,234,000	1,738,710	1,905.190	1,748,100	1,904,515
Stock, end each year	185,560	230,010	289,010	259,340	321,080	265,470	464,130	538,370	561,430	784,700	897,060	1,060,560	545,790	451,940	490,050	558,340	521,120	494,600
Exported - - -	85,850	102,100	108,900	125,150	109,050	104,850	116,200	116,900	126,450	108,350	130,000	119,900	194,300	214,350	189,500	256,300	272,400	263,500
Taken for Home use	890,912	944,157	1,032,930	1,077,928	1,259,910	1,062,610	1,285,510	1,151,230	1,205,010	1,402,270	1,440,440	1,574,670	1,564,440	1,113,500	1,505,100	1,586.600	1,512,920	1,662,540
American Crop -	1,205,400	1,254,300	1,360,500	1,422,900	1,801,500	1,360,500	2,177,800	1,634,900	1 683,600	2,378,900	2,030,000	2,420,300	2,100,537	1,780,000	2,347,600	2,728,600	2,096,700	2,355,000

Prices this Date.		Upland.	New Orleans.	Mobile.	Sea Island.	Pernambuco.	Bahia.	Maranham.	Paras.	Egyptian.	Surat.	Bengal.
1851.	Fair	5*d.* @ 0*d.*	5⅛*d.* @ 0*d.*	5*d.* @ 0*d.*	13½*d.* @ 0*d.*	6¼*d.* @ 0*d.*	6*d.* @ 0*d.*	6⅛*d.* @ 0*d.*	0*d.* @ 0*d.*	6½*d.* @ 0*d.*	3½*d.* @ 0*d.*	3¼*d.* @ 0*d.*
	Extreme	4 — 6	4 — 8	4 — 6	10 — 24	5¾ — 7	5¼ — 6⅜	5¼ — 7⅓	0 — 0	5¼ — 8½	2½ — 4⅛	3 — 4
1850.	Fair	7⅞ — 0	8⅛ — 0	8 — 0	15 — 0	8⅝ — 0	8⅜ — 0	8½ — 0	0 — 0	8½ — 0	5⅝ — 0	5¾ — 0
	Extreme	6⅝ — 8½	6¾ — 10	6⅝ — 8¼	11 — 24	7⅞ — 9	7⅝ — 8¾	7¾ — 9	0 — 0	7½ — 10	4¾ — 6½	5¾ — 6
1849.	Fair	6⅛ — 0	6¾ — 0	6¼ — 0	12½ — 0	6¼ — 0	6⅜ — 0	6⅜ — 0	0 — 0	6½ — 0	4¼ — 0	4¼ — 0
	Extreme	5⅞ — 7	5⅞ — 8	5⅞ — 7½	9¼ — 20	6⅛ — 7½	6 — 7	6 — 7	0 — 0	6 — 8 1-5	3¾ — 5	4 — 5

STOCK OF COTTON IN LIVERPOOL, LONDON, AND GLASGOW, FOR THE YEARS 1847, 1848, 1849, 1850, and 1851.

	Sea Island.	Upland.	New Orleans.	Alabama and Mobile.	Brazil.	Demerara and Berbice.	West India, &c.	Egyptian.	East Indies.	Total Stock.
In Liverpool -	2,330	60,480	121,560	51,750	49,480	150	3,820	19,830	114,330	423,730
London, &c. -	- -	2,150	- -	- -	40	60	280	160	53,630	56,320
Glasgow - -	70	2,470	2,340	2,660	- -	- -	- -	2,920	4,090	14,550
Total in 1851 -	2,400	65,100	123,900	54,410	49,520	210	4,100	22,910	172,050	494,600
Total in 1850 -	4,650	93,340	134,780	39,940	68,650	40	1,420	34,920	143,380	521,120
Total in 1849 -	6,050	76,760	171,820	62,680	95,170	90	1,900	38,000	105,870	558,340
Total in 1848 -	7,050	58,170	145,820	61,190	68,590	60	2,570	16,920	135,680	496,050
Total in 1847 -	7,310	51,930	130,650	49,430	59,290	100	2,030	26,090	125,200	451,940

GENERAL IMPORT, STOCK, AND CONSUMPTION OF COTTON FOR THE YEAR 1851.

	America.	Brazil.	West India, Demerara, Smyrna, &c.	Egypt.	East India.	Total.
Stock on hand, 1st January, 1851.	272,710	68,650	1,460	34,920	143,380	521,120
Imported from 1st Jan. to 31st Dec.	1,396,950	107,690	5,760	67,340	326,780	1,904,520
Total supply for 1851 - - -	1,669,660	176,340	7,220	102,360	470,160	2,425,640
Stock on hand, 31st Dec. 1851. -	215,810	49,520	4,310	22,910	172,050	494,600
	1,423,850	126,820	2,910	79,350	298,110	1,931,040
Export to the Continent, &c. -	151,950	12,000	200	960	103,450	268,500
Taken for home consumption 1851.	1,271,900	114,820	2,710	78,450	194,660	1,662,540
Or average per week - - -	24,458	2,208	52	1,509	3,744	31,971
Weekly average in 1850 - -	20,705	3,339	105	1,572	3,373	29,094

COTTON SPINNING. Messrs. Tatham, Cheetham, and Duncan, obtained in 1846 a patent for sundry improvements in apparatus for cotton spinning. Their first invention applies to the scutcher, a machine by which the cotton is cleansed and lapped in a compact and even sheet or lap upon a roller preparatory to its being fed into the carding engine, and consists in a new arrangement of rollers for compressing or calendering the sheet of cotton previous to its being lapped upon the roller; and also in a new method of weighting the calendering rollers, whereby the pressure is gradually increased as the sheet of cotton approaches the lap. The second part of the invention consists in the employment of an apparatus for collecting the fibres of cotton from the dust which is blown by the fan from the scutcher.

The third part of the invention is an improvement upon machinery patented by Tatham & Cheetham in March, 1844, which caused the sliver to be twisted as it is delivered from the carding engine into the tin-can receptacle.

The fourth relates to the application of gutta percha tintawan for covering rollers used in the several machines employed in cotton spinning. These substances may be used either alone, or combined with sulphurets, &c.

The fifth invention relates to the "flyer" now usually employed in "presser frames." Here the legs or arms of the flyer (being jointed above the top or elbow) are caused to act upon the bobbin like tongs, and thus dispense with the small spur or level at the bottom of the flyer, called the presser. Through the boss or upper part of the flyer the sliver or roving of cotton passes to the hollow arm. The top part and arms are joined together, and swivel upon a central pin or stud. At this joint a coiled spring, exactly similar to the ordinary snuffers-spring, is inserted, one end of which is to be fast to the head, and the other end to the arm of the flyer; whereby the desired elasticity is imparted to the arms, to effect the pressure on the bobbin. The lower end of the arm must be smaller, to lap one or two folds of the roving around it to create the drag usually obtained by the folds around the common press or level.—*Newton's Journal*, xxxi., p. 77.

In cotton spinning machines the roving and slubbing frames move at a great velocity, and are liable to vibrations, and consequently to much wear and tear, which Mr. Edmund Hartley, of Oldham, has tried to remedy by patented contrivances, while the speed is increased. He has also sought to improve the backing off motion in self-actor mules. For description of his invention, see *Newton's Journal*, vol. xxxvi., p. 300.

COTTON (GUN). M. Schönbein, the patentee, states that the invention consists in the manufacture of explosive compounds applicable to mining purposes and to projectiles, and as substitutes for gunpowder, by treating and combining matters of vegetable origin with nitric and sulphuric acids.

The matter of vegetable origin which he prefers, as being best suited for the purposes of the invention, is cotton, as it comes into this country, freed from extraneous matters; and it is stated to be desirable to operate on the clean fibres of the cotton in a dry state. The acids are nitric acid of from 1·45 to 1·50 specific gravity, and sulphuric acid of 1·85 specific gravity.

The acids are mixed together in the proportions of 1 measure of nitric to 3 measures of sulphuric acid, in any suitable or convenient vessel not liable to be affected by the acids. A great degree of heat being generated by the mixture, it is left to cool until its temperature falls to 60° or 50° Fahr. The cotton is then immersed in it, and in order that it may become thoroughly impregnated or saturated with the acids, it is stirred with a rod of glass or other material not affected by the acids. The cotton should be introduced in as open a state as practicable. The acids are then poured or drawn off, and the cotton gently pressed by a presser of glazed earthenware, to press out the acids, after which it is covered up in the vessel, and allowed to stand for about an hour. It is subsequently washed in a continuous flow of water until the presence of the acids is not indicated by the ordinary test of litmus paper. To remove any uncombined portions of the acids which may remain after the cleansing process, the patentee dips the cotton in a weak solution of carbonate of potash, composed of 1 oz. of carbonate of potash to 1 gallon of water, and partially dries it by pressing, as before. The cotton is then highly explosive, and may be used in that state; but, to increase its explosive power, it is dipped in a weak solution of nitrate of potash, and, lastly, dried in a room heated by hot air or steam to about 150° Fahr.

It is considered probable that the use of the solutions of carbonate of potash and nitrate of potash may be dispensed with, although actual experience does not warrant such an omission. The patentee remarks, that nitric acid may be employed alone in the manufacture of explosive compounds, but that, as far as his experience goes, the article when so manufactured is not so good, and far more costly.

When used, care should be taken to employ a much less quantity by weight, to produce the same result, than of gunpowder; and it has been found that three parts by weight of the cotton produce the same effect as eight parts by weight of the Tower-proof gunpowder.

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The cotton, when prepared in the manner before mentioned, may be rammed into a piece of ordnance, a fowling-piece, or musket; or may be made up into the shape of cartridges; or may be pressed, when damp, into moulds of the form of the bore of the piece of ordnance for which it is intended, so that, when dried, it shall retain the required figure; and it may also be placed in caps, like percussion caps, and made to explode by impact. Lastly, the patentee states, that although he prefers the use of cotton, other matters of vegetable origin may be similarly treated with acids to form an explosive compound, and that acids of an inferior specific gravity may be employed.

Cotton (Gun), *spontaneous combustion of*, (*by Dr. Gladstone*).—"Gun-cotton, as commonly produced, especially for preparation of *collodium*, is a mixture of two distinct though analogous substances. The one is designated pyroxyline, and has the formula

$$C_{24}\left\{\begin{matrix}H_{15}\\5NO\end{matrix}\right\}O_{20}$$

It leaves no residuum on explosion; is insoluble in ether, &c. The other has received the appellation Cotton-xyloidine, and the formula

$$C_{24}\left\{\begin{matrix}H_{17}\\3NO_4\end{matrix}\right\}O_{20}$$

It leaves a residue on explosion; is soluble in ether, &c.

"*Pyroxyline.*—This substance is produced only when cotton or cotton-xyloidine is immersed in a mixture of nitric acid, of sp. gr. 1·5, with strong oil of vitrol. Although it contains so large an amount of oxide of nitrogen, I am acquainted with no clear instance in which it has undergone spontaneous decomposition. Specimens obtained by the action of the mixed acids on cotton-xyloidine have shown no indications of change; and pyroxyline obtained in a compact translucent form, from solution in acetic ether, has also remained unaltered.

"*Cotton-Xyloidine.*—This may be prepared in a state of purity, and in a pulverulent condition, by dissolving cotton or pyroxyline in nitric acid of about sp. gr. 1·45, and precipitating the substance by water.

"Several specimens of this compound made from both sources have hitherto suffered no decompositions, but they have been generally kept in the dark. One sample of precipitated cotton-xyloidine placed in a stoppered bottle remained in a cupboard, the door of which was sometimes opened and sometimes closed. After the lapse of about three years it suddenly began to evolve nitric oxide and water: the action continued for a few weeks, and then nothing remained but a small quantity of a transparent gummy mass of a light brown color, and possessed of a very peculiar odor. Several months produced no further alteration.

"This product of decomposition, which had about the tenacity and consistency of ordinary gum, was not explosive: when heated in a closed tube, *per se*, it gave off red fumes, and afterward swelled up, being carbonized, and evolving empyreumatic oils. It was found to be insoluble in cold water, but when boiled in that liquid, it swelled up as a gelatinous mass, and became disintegrated. There resulted a solution which reddened litmus paper slightly, containing, however, no oxalic acid, but a small quantity of another acid, which gave a flocculent white-lead salt, insoluble in excess of acetic acid; the substance in question, though insoluble in cold water, dissolved readily in aqueous solution of potash: yet it appeared to be altered in combining with the alkali, for it was not re-precipitated when the potash was supersaturated by an acid.

"*Starch-Xyloidine.*—This is the well-known substance produced when starch is treated with strong nitric acid, and water is added to the viscid mass. Its composition varies; but it is in general analogous to, if not identical with, that ascribed above to cotton-xyloidine.

"A large specimen, freely exposed to the light during more than four years, remained unaltered.

"*Higher Starch Compound.*—When ordinary starch-xyloidine is treated with a mixture of fuming nitric and sulphuric acids, and subsequently washed, it is found to have greatly increased in weight. The resulting substance is more combustible than the original xyloidine, and differs from it in several respects, but is not identical with the pyroxyline obtained from woody fibre.

"A sample of this product, which had been left eight or nine months in a room where light freely entered, was found wholly decomposed; nitrous fumes and vapor of water had been evolved, leaving a dark sticky residue. This new substance was soluble in water and in alcohol; crystallizing from the latter in tufts, which under the microscope had a beautiful arborescent appearance. It remained a couple years or more dissolved in a very small quantity of water. What changes may have taken place in it during that period is unknown, since no proper examination had been previously made, but after the lapse of that time, the solution was found to be almost black and strongly acid.

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When neutralized with an alkali it gave a copious precipitate on the addition of nitrate of silver, and a flocculent salt, or rather mixture of salts, with chloride of calcium which, when dried and heated with hydrate of potash, evolved ammonia. At the bottom of the vessel containing the aqueous solution there had grown a compound crystal, transparent and colorless, with the exception of a few brown specks. It had the rhomboidal form which oxalic acid usually assumes, and upon further examination and analysis proved to be that substance.

"A small sample of this same starch compound, which had been washed repeatedly with glacial acetic acid for complete purification, and which had been kept constantly in the dark was found to have suffered decomposition, nothing remaining but a viscous acid liquid. When examining these decomposed explosive compounds, I found in my laboratory a bottle filled with a brown sticky mass; the label having been destroyed by evolved acid, it could not be positively identified, but I have good reason to believe it had originally been the higher starch compound: the substance had a strong odor of hydrocyanic acid. Its solution, in either water or alcohol, had a strong acid reaction. It gave no precipitate with chloride of calcium. Flocculent salts containing metallic oxides or baryta, all easily soluble in nitric acid, were readily produced. Its combinations with the alkalis gave dark brown aqueous solutions, from which they separated in an amorphous form on evaporation, but though exceedingly soluble in water, they were precipitated on the addition of alcohol. The mass was probably a mixture of different acids, principally non-azotized, for little nitrogen was discoverable; and although oxalic acid itself was absent, it is by no means improbable that some higher members of the series, $Cn\ Hn_1\ O_4$ were present.

"*Nitro-Mannite.*—This substance, first described by MM. Flores Domonte and Menard, is formed when mannite is dissolved in fuming nitric acid, and precipitated by sulphuric acid. Its formula, according to Strecker, is $C_{12}\ H_8\,(NO_4)\ O_{12}$. It is the only known crystallizable body belonging to this group.

"My sample of nitro-mannite kept in a glass tube, generally in the dark, has suffered some decomposition; acid fumes have been given off, but the action has not proceeded far.

"*Sugar Compound.*—It is well known that cane-sugar submitted to the action of mixed nitric and sulphuric acids is converted into a pasty explosive substance, readily soluble in alcohol, but insoluble in water, to which, however, it communicates an intensely bitter flavor. According to the observations of H. Vohl, several different compounds are produced simultaneously in this reaction. Diabetic sugar similarly treated gives a similar substance.

"I have kept samples of this product, some of which had been merely kneaded with water until the acid was removed, others regained from solution in alcohol. They have shown little signs of decomposition.

"*Milk-Sugar Compound.*—By the same treatment a substance is obtained from milk-sugar closely resembling that just described. Like the previous compound, it can be purified by solution in alcohol, but does not present itself in a crystalline form.

"A sample kept in paper was found to be much decomposed.

"*Caramel Compound.*—I procured a similar compound from pure caramel, prepared by means of absolute alcohol. The caramel having been dried and pounded, was placed in fuming nitric acid: it dissolved; upon the addition of sulphuric acid, a dark-colored oil separated, which became hard and yellow when washed with water. It was soluble in alcohol, but came out from solution without crystallizing, and always of the same color. The compound bore a close resemblance in its various properties to those obtained from sugar.

"The sample kept by me has suffered little or no alteration.

"*Gum Compound.*—At least two different substances of this explosive character may be produced by the action of nitric acid on gum. If the gum be treated with the fuming acid, it dissolves into a mucilaginous solution, from which water precipitates a white body, slightly soluble in that liquid, and very soluble in alcohol. A sample of this substance has not yet suffered any decomposition.

"If sulphuric acid be added to the solution of gum in fuming acid, it precipitates a white substance resembling that from sugar, but not nearly so soluble in alcohol, and very slightly in ether. Moreover, it is only softened, not melted, by a temperature of 212° Fahr. No specimen of this compound was preserved.

"While treating upon this subject, it may not be amiss to append a few observations upon another decomposition of pyroxyline. When good gun-cotton is heated at a temperature a little exceeding that of boiling water, it becomes brown in color, and is disintegrated. The odor of nitrous fumes, along with that of some cyanogen compound, is very perceptible. It thus becomes explosive at a lower temperature than formerly, a fact which may account for some of those hitherto unexplained accidents which have arisen from this article, for it is evident that gun-cotton exposed for some time to a

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degree of heat quite insufficient under ordinary circumstances to cause explosion, may yet be eventually dissipated from the formation of this product.

"The brown substance thus obtained underwent no visible alteration in the space of four years. When examined lately it was found to be very soluble in water, but insoluble in alcohol or ether. Its aqueous solution tasted somewhat bitter, it reacted slightly acid, no crystals were obtained on evaporation. When boiled with a solution of potash, it evolved ammonia. When mixed with a salt of lead or copper it formed brown flocculent precipitates, but none appeared with a silver or lime salt. The organic substance which fell in combination with oxide of lead, contained a large amount of nitrogen. That portion of the fibre which had not become brown with heat was found to be no longer pyroxyline; when freed from the brown matter by washing with water, and dried, it left little residue on explosion; but on the other hand, it dissolved very readily in ether, alcohol, or cold sulphuric acid; properties of cotton-xyloidine, but not of the original substance. When, however, the manner of its production is considered, we can hardly conceive it identical with a body which would require the introduction of two atoms of hydrogen if formed from pyroxyline. Whether this change which gun-cotton undergoes at a high temperature is at all analogous to the spontaneous decomposition mentioned above, can scarcely be determined, but the presence of azotized compounds in considerable quantity, and of ammonia, rather indicates the reverse.

"The *rationale* of these decompositions is far from being elucidated by the observations here recorded, but as the substances themselves are not now in existence, nor are capable of being procured without long delay, I cannot pursue the investigation further. The only general conclusion which can be drawn appears to be, that several substances of the character above described have a tendency to suffer spontaneous decomposition from being oxidized into non-azotized acids at the expense of the peroxide of nitrogen, NO_4, they contain, which is reduced to the condition of nitric oxide, NO_2, and evolved as such, a portion of water being always given off at the same time."

COURT PLASTER is a considerable object of manufacture. It is made as follows:

Black silk is strained and brushed over ten or twelve times with the following preparation:—Dissolve ½ an ounce of balsam of benzoin in 6 ounces of rectified spirits of wine; and in a separate vessel dissolve 1 ounce of isinglass in as little water as may be. Strain each solution, mix them, and let the mixture rest, so that any undissolved parts may subside; when the clear liquid is cold it will form a jelly, which must be warmed before it is applied to the silk. When the silk coated with it is quite dry it must be finished off with a coat of a solution of 4 ounces of Chian turpentine in 6 ounces of tincture of benzoin, to prevent its cracking.*

COW DUNG SUBSTITUTE, in calico printing. Sulphate, carbonate and phosphate of lime and soda.

CRANES, *Tubular, of Mr. W. Fairbairn.*—Among the many happy applications of the hollow-girder system of our great engineer, this is one of the most ingenious.

"*Fig.* 425 is a vertical section of a crane, constructed according to my said invention, and calculated for lifting or hoisting weights up to about 8 tons. *Fig.* 426 is an elevation of the same; *figs.* 427, 428, 429, and 430, are cross-sections, on the lines *a b*, *c d*, *e f*, *g h*; and *fig.* 431 a transverse vertical section on the line *i k*. A A is the jib, which in its general outline, is of a crane-neck form, but rectangular in its cross-section, as particularly shown in *figs.* 428, 429, and 430. The four sides are formed of metal plates, firmly riveted together. Along the edges the connection of the plates is effected by means of pieces of angle iron. The connections of the plates at the cross-joints on the convex or upper side of the jib, are made by the riveting on of a plate, which covers or overlaps the ends of the two plates to be joined; the rivets at this part are disposed as represented in *fig.* 432 (a plan of the top plates), and known as 'chain riveting;' B B is the pillar, which is firmly secured by a base plate *p*, to a stone foundation B; and fits at top into a cup-shaped bearing C, which is so firmly secured to the side plates of the jib, at or near to the point where the curvature commences, and on which bearing the jib is free to revolve. *Fig.* 431 is a transverse vertical section of the lower part of the jib, showing the manner of fitting the bearings for the chain-barrel (which is placed in the interior), and the spindles and shafts of the wheel-geering, by which the power is applied there to D, is the chain pulley, which is inserted in an aperture formed in the top of the jib. The chain passing over this pulley, enters the interior of the crane, and is continued down to the chain barrel. E is a pulley or roller, which is interposed about half-way between the chain-pulley and the chain-barrel, for the purpose of preventing the chain rubbing against the plates. *Fig.* 433 is a plan of the lower plates.

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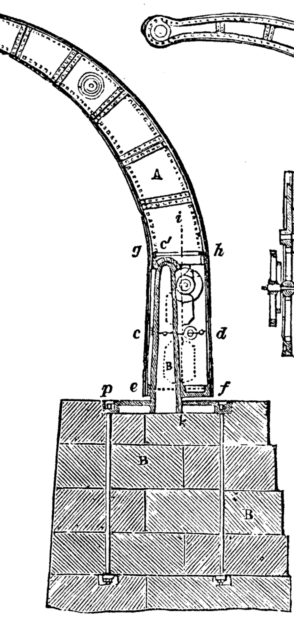
* Paris's Pharmacologia.

Fig. 434 is a vertical section of another crane constructed upon the same principle as that just described, but calculated for lifting much greater weights (says 20 tons); it differs in having the lower or concave side A A, of the jib strengthened by means of three additional plates B B B, whereby the interior is divided into one large and three smaller cells, as shown in *figs.* 435 and 436, which are cross sections upon the lines *a b*, and *c d* of *fig.* 434. This arrangement of the cells to strengthen the lower or concave side is advisable, in order to obtain sufficient resistance to the compression exerted by the load lifted, without unnecessarily increasing the weight of the other parts. The tension exerted upon the upper or convex plates does not require so much materials to withstand it; C, is the toe of the jib, which rests in a step formed in the bottom of the cylindrical castings D, which is built into the masonry forming the basis of the machine. E E are two of a set of pulleys, which are mounted between two rings F F, and serve an anti-friction rollers for the upper bearing of the jib. The lowermost of the rings F F, rests upon a set of rollers G G, which are fitted into the top of the casting D, so that as the jib is turned round, the rings F F, and the anti-friction rollers which they carry, have perfect freedom to move along with it; H is a platform, upon which the persons working the machine may stand, and which supports a column I, within which there is mounted a spindle K, the lower end of which has keyed to it a pinion L, which gears into a circular rack M M, bolted to the top of the cylindrical casing D. N is a worm-wheel keyed to the top of the spindle K, into which an endless screw, worked by

425



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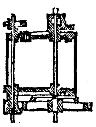

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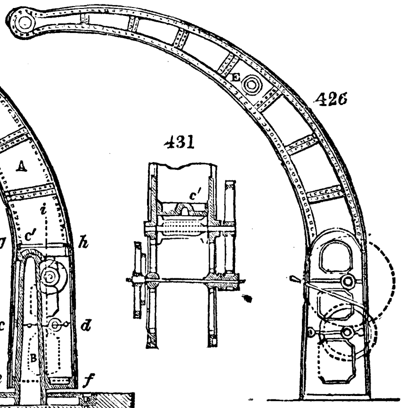

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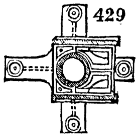

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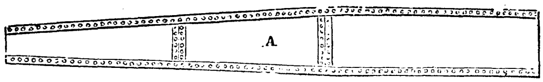

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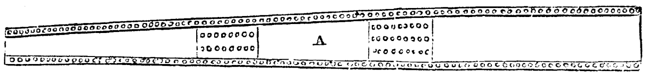
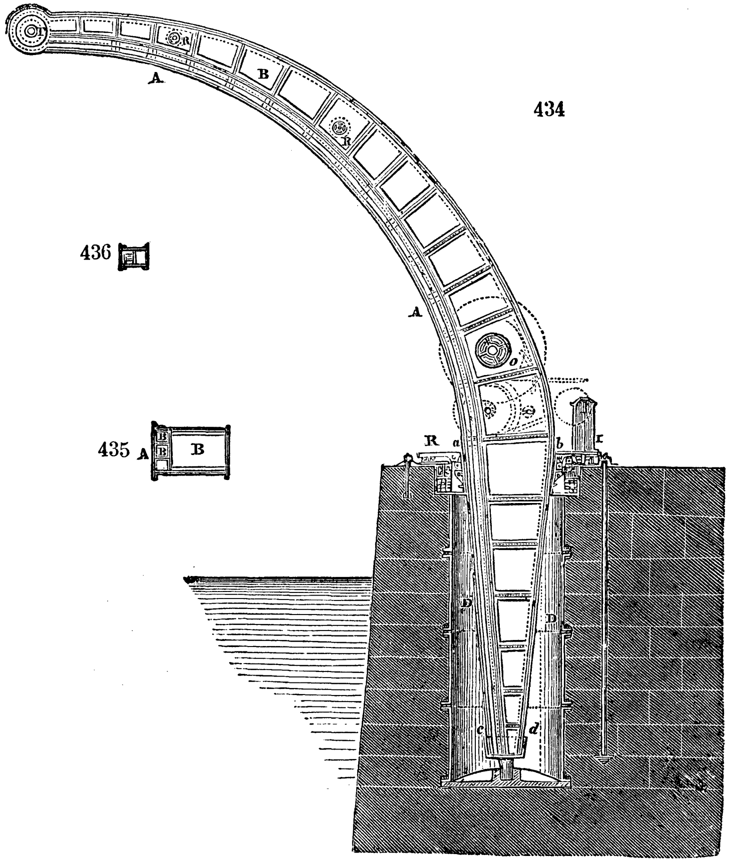


a hand-wheel, is geered, so that, by turning the hand-wheel, the jib of the crane is made to move round in any required direction. O is the chain-barrel; P the chain-wheel; R R pulleys or rollers which support the chain, and prevent its rubbing against the plates of the jib.

"In the cranes and hoisting machines which I have described, the chain-barrels are inclosed within the jib, and the spindles of the wheel-gearing are also inside; and this



is the disposition of those parts, which I prefer; but it will be obvious that they may be also placed outside of the jib, in a manner similar to that generally followed in the construction of ordinary cranes. And having now described my said invention, and in what manner the same is to be performed, I declare that what I claim is the construction of cranes and other light lifting or hoisting machines, with jibs composed of a series of metal plates, arranged and combined so as to form a connected series of tubular or cellular compartments, as before exemplified and described."

CRAPE. (*Crêpe*, Fr.; *Krepp*, Germ.) A transparent textile fabric, somewhat like gauze, made of raw silk, gummed and twisted at the mill. It is woven with any crossing or tweel. When dyed black, it is much worn by ladies as a mourning dress. Crapes are crisped (*crepês*) or smooth; the former being double, are used in close mourning, the latter in less deep. White crape is appropriate to young unmarried females, and to virgins on taking the veil in nunneries. The silk destined for the first is spun harder than for the second; since the degree of twist, particularly for the warp, determines the degree of crisping which it assumes after being taken from the oom. It is for this purpose steeped in clear water, and rubbed with prepared wax.

Crapes are all woven and dyed with the silk in the raw state. They are finished with a stiffening of gum water.

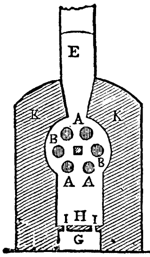
Crape is a Bolognese invention, but has been long manufactured with superior excellence at Lyons in France, and Norwich in England. There is now a magnificent fabric of it at Yarmouth, by power-loom machinery.

There is another kind of stuff, called *crépon*, made either of fine wool, or of wool and silk, of which the warp is twisted much harder than the weft. The *crépons* of Naples consist altogether of silk.

CRAYONS. (Eng. and Fr.; *Pastelstifte*, Germ.) Slender, soft, and somewhat friable cylinders, variously colored for delineating figures upon paper, usually called chalk drawings. Red, green, brown, and other colored crayons, are made with fine pipe or china clay paste, intimately mixed with earthy or metallic pigments, or in general with body or surface colors, then moulded and dried. The brothers Joel, in Paris, employ as crayon cement the following composition: 6 parts of shellac, 4 parts of spirit of wine, 2 parts of turpentine, 12 parts of a coloring powder, such as Prussian-blue, orpiment, white lead, vermilion, &c., and 12 parts of blue clay. The clay being elutriated, passed through a hair sieve, and dried, is to be well incorporated by trituration with the solution of the shellac in the spirit of wine, the turpentine, and the pigment; and the doughy mass is to be pressed in proper moulds, so as to acquire the desired shape. They are then dried by a stove heat.

In order to make cylindrical crayons, a copper cylinder is employed, about 2 inches in diameter, and $1\frac{1}{2}$ inches long, open at one end, and closed at the other with a perforated plate, containing holes corresponding to the sizes of the crayons. The paste is introduced into the open end, and forced through the holes of the bottom by a piston moved by a strong press. The vermicular pieces that pass through are cut to the proper lengths, and dried. As the quality of the crayons depends entirely upon the fineness of the paste, mechanical means must be resorted to for effecting this object in the best manner. The following machine has been found to answer the purpose exceedingly well.

440



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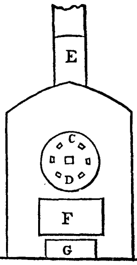

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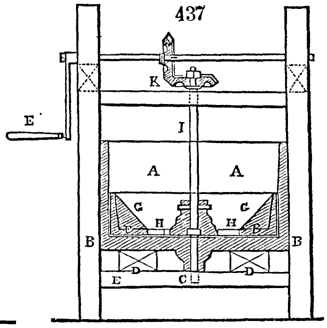

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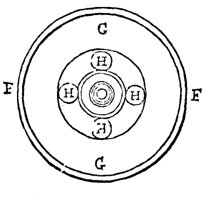

Fig. 437 is a vertical section through the centre of the crayon mill. *Fig.* 438 is a view of the mill from above. A, the mill tub, whose bottom B must be a hard flat plate of cast iron; the sides A being of wood or iron at pleasure. In the centre of the bottom there is a pivot C, screwed into a socket cast upon the bottom, and which may be strengthened by two cross bars D, made fast to the frame E. F, the millstone of cast-iron, concave, whose diameter is considerably smaller than that of the vessel A; it is furnished within with a circular basin of wood G, which receives the materials to be ground, and directs them to the holes H, which allow them to pass down between the under part of the muller, and the bottom of the tub, to undergo trituration.

By the centrifugal motion, the paste is driven toward the sides of the vessel, rises over the sides of the muller, and comes again through the holes H, so as to be repeatedly subjected to the grinding operation. This millstone is mounted upon an upright shaft I, which receives rotary motion from the bevel-wheel work K, driven by the winch L.

The furnace in which some kinds of crayons, and especially the factitious black-lead pencils, are baked, is represented in *fig.* 439, in a front elevation; and in *fig.* 440, which is a vertical section through the middle of the chimney.

A A, six tubes of greater or less size, according as the substance of the crayons is a better or worse conductor of heat. These tubes, into which the crayons intended for baking are to be put, traverse horizontally the laboratory B of the furnace, and are supported by two plates C, pierced with six square holes for covering the axes of the tubes A. These two plates are hung upon a common axis D; one of them, with a ledge, shuts the cylindrical part of the furnace, as is shown in the figure. At the extremity of the bottom, the axis D is supported by an iron fork fixed in the brickwork; at the front it crosses the plate C, and lets through an end about 4 inches square to receive a key, by means of which the axis D may be turned round at pleasure, and thereby the two plates C, and the six tubes A, are thus exposed in succession to the action of the fire in an equal manner upon each of their sides. At the two extremities of the furnace are two chimneys E, for the purpose of diffusing the heat more equably over the body of the crayons. F, *fig.* 439, is the door of the fire-place, by which the fuel is introduced; G, *fig.* 440, the ash-pit; H, the fire-place; I, holes of the grate which separate the fire-place from the ash-pit; K, brickwork exterior to the furnace.

General Lomet proposes the following composition for red crayons. He takes the softest hematite, grinds it upon a porphyry slab, and then carefully elutriates it. He makes it into a plastic paste with gum arabic and a little white soap, which he forms by moulding, as above, through a syringe, and drying, into crayons. The proportions of the ingredients require to be carefully studied.

CRAYONS, *lithographic.* Various formulæ have been given for the formation of these crayons. One of these prescribes, white wax, 4 parts; hard tallow-soap, shellac, of each 2 parts; lamp black, 1 part. Another is, dried tallow soap and white wax, each 6 parts; lamp black, 1 part. This mixture being fused with a gentle heat, is to be cast into moulds for forming crayons of a proper size.

CREOSOTE, or the *flesh-preserver*, from κρεας and σωζω, is the most important of the five new chemical products obtained from wood tar by Dr. Reichenbach. The other four, *paraffine, eupione, picamar*, and *pittacal*, have hitherto been applied to no use in the arts, and may be regarded at present as mere analytical curiosities.

Creosote may be prepared either from tar or from crude pyroligneous acid. The tar must be distilled till it acquires the consistence of pitch, and at the utmost till it begins to exhale the white vapors of paraffine. The liquor which passes into the receiver divides itself into 3 strata, a watery one in the middle, placed between a heavy and a light oil. The lower stratum alone is adapted to the preparation of creosote.

1. The liquor, being saturated with carbonate of potash, is to be allowed to settle, and the oily matter which floats at top is to be decanted off. When this oil is distilled, it affords, at first, products lighter than water, which are to be rejected, but the heavier oil which follows is to be separated, washed repeatedly by agitation, with fresh portions of dilute phosphoric acid, to free it from ammonia, then left some time at rest, after which it must be washed by water from all traces of acidity, and finally distilled along with a new portion of dilute phosphoric acid, taking care to *cohobate*, or pour back the distilled product repeatedly into the retort.

2. The oily liquid thus rectified is colorless; it contains much *creosote*, but at the same time some *eupione*, &c. It must therefore be mixed with potash ley at 1·12 sp. grav., which dissolves the creosote. The upione floats upon the surface of that solution, and may be decanted off. The alkaline solution is to be exposed to the air, till it blackens by decomposition of some foreign matter. The potash being then saturated with dilute sulphuric acid, the creosote becomes free, when it may be decanted or syphoned off and distilled.

3. The treatment by potash, sulphuric acid, &c., is to be repeated upon the brownish creosote till it remains colorless, or nearly so, even upon exposure to air. It must be now dissolved in the strongest potash ley, subjected to distillation anew, and, lastly, redistilled with the rejection of the first products which contain much water, retaining only the following, but taking care not to push the process too far.

In operating upon pyroligneous acid, if we dissolve effloresced sulphate of soda in it to saturation, at the temperature of 167° F., the creosote oil will separate, and float upon the surface. It is to be decanted, left in repose for some days, during which it will part with a fresh portion of the vinegar and salt. Being now saturated while hot, with carbonate of potash, and distilled with water, an oily liquor is obtained, of a pale yellow color. This is to be rectified by phosphoric acid, &c., like the crude product of creosote from tar.

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Creosote is apparently composed of 76·2 carbon, 7·8 hydrogen, and 16·0 oxygen, in 100 parts. It is an oily-looking liquid, slightly greasy to the touch, void of color, acrid burning taste, and capable of corroding the epidermis in a short time. It possesses a penetrating disagreeable smell, like that of highly smoked hams, and, when inhaled up the nostrils, causes a flow of tears. Its specific gravity is 1·037, at 58° F. Its consistence is similar to that of oil of almonds. It has no action upon the colors of litmus or turmeric, but communicates to white paper a stain which disappears spontaneously in a few hours, and rapidly by the application of heat.

It boils without decomposition at 398° F., under the average barometric pressure, remains fluid at 16° F., is a non-conductor of electricity, refracts light powerfully, and burns in a lamp with a ruddy smoky flame.

When mixed with water at 58° F. it forms two different combinations, the first being a solution of 1 part of creosote in 400 of water; the second, a combination of 1 part of water with 10 parts of creosote. It unites in all proportions with alcohol, hydric ether, acetic ether, naptha, eupione, carburet of sulphur, &c.

Creosote dissolves a large quantity of iodine and phosphorus, as also of sulphur with the aid of heat, but it deposites the greater part of them in crystals, on cooling. It combines with potash, soda, ammonia, lime, baryta, and oxyde of copper. Oxyde of mercury converts creosote into a resinous matter, while itself is reduced to the metallic state. Strong sulphuric and nitric acids decompose it.

Creosote dissolves several salts, particularly the acetates, and the chlorides of calcium and tin; it reduces the nitrate and acetate of silver. It also dissolves indigo blue; a remarkable circumstance. Its action upon animal matters is very interesting. It coagulates albumen, and prevents the putrefaction of butchers' meat and fish. For this purpose these substances must be steeped a quarter of an hour in a weak watery solution of creosote, then drained and hung up in the air to dry. Hence Reichenbach has inferred that it is owing to the presence of creosote that meat is cured by smoking; but he is not correct in ascribing the effect to the mere coagulation of the albumen, since *fibrine* alone, without creosote, will putrefy in the course of 24 hours, during the heats of summer. It kills plants and small animals. It preserves flour paste unchanged for a long time.

Creosote exists in the tar of beech-wood, to the amount of from 20 to 25 per cent., and in crude pyroligneous acid, to that of 1½.

It ought to be kept in well-stoppered bottles, because when left open it becomes progressively yellow, brown, and thick.

Creosote has considerable power upon the nervous system, and has been applied to the teeth with advantage in odontalgia, as well as to the skin in recent scalds. But its medicinal and surgical virtues have been much exaggerated. Its flesh-preserving quality is rendered of little use, from the difficulty of removing the rank flavor which it imparts.

Having been employed by a chemical manufacturer to examine his creosote, and compare it with others with a view to the improvement of his process, I found that the article, as made by eminent houses, differed considerably in its properties.

The specific gravities varied in the several specimens as follows: 1, a specimen given me by Messrs. Zimmer and Sell, at their factory in Sachsenhausen, by Frankfort-on-the-Maine, had a specific gravity of 1·0524; 2, a sample made in the north of England, sp. gr. 1·057, and its boiling point varied from 370° to 380° Fahr. Mr. Morson's creosote, which is much esteemed, has a sp. gr. of 1·070, and boils first at 280°, but progressively rises in temperature up to 420°, when it remains stationary. The German creosote was distilled from the tar of the pyrolignous acid manufacture. Creosote, I believe, is often made from Stockholm tar. Berzelius gives the sp. gr. of creosote at 1·037, and its boiling point at 203° C.=397·4° F. I deemed it useless to subject to ultimate analysis products differing so considerably in their physical properties. They were all very soluble in potash lye.

CROSS-FLUCKANS or FLOOKANS. The name given by the Cornish miners to clay veins of more ancient formation.

CRUCIBLES (*Creusets*, Fr.; *Schmelztiegel*, Germ.) are small conical vessels, narrower at the bottom than the mouth, for reducing ores in docimasy by the dry analysis, for fusing mixtures of earthy and other substances, for melting metals, and compounding metallic alloys. They ought to be refractory in the strongest heats, not readily acted upon by the substances ignited in them, not porous to liquids, and capable of bearing considerable alternations of temperature without cracking; on which account they should not be made too thick. The best crucibles are formed from a pure fire-clay, mixed with finely-ground *cement* of old crucibles, and a portion of black-lead or graphite. Some pounded coke may be mixed with the plumbago. The clay should be prepared in a similar way as for making pottery ware; the vessels after being formed must be slowly dried, and then properly baked in the kiln. Crucibles formed of a mixture of 8 parts in bulk of Stourbridge clay and cement, 5 of coke, and 4 of graphite,

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have been found to stand 23 meltings of 76 pounds of iron each, in the Royal Berlin foundry. Such crucibles resisted the greatest possible heat that could be produced, in which even wrought iron was melted, equal to 150° or 155° Wedgewood; and bore sudden cooling without cracking. Another composition for brass-founding crucibles is the following: ½ Stourbridge clay; ¼ burned-clay cement; ⅛ coke powder; ⅛ pipe clay. The pasty mass must be compressed in moulds. The Hessian crucibles from Great Almerode and Epeterode are made from a fire-clay which contains a little iron, but no lime; it is incorporated with siliceous sand. The dough is compressed in a mould, dried and strongly kilned. They stand saline and leaden fluxes in docimastic operations very well; are rather porous on account of the coarseness of the sand, but are thereby less apt to crack from sudden heating or cooling. They melt under the fusing point of bar iron. Beaufoy in Paris has lately succeeded in making a tolerable imitation of the Hessian crucibles with a fire-clay found near Namur in the Ardennes.

Berthier has published the following elaborate analyses of several kinds of crucibles:—

	Hessian.	Beaufay.	English for Cast Steel.	St. Etienne for Cast Steel.	Glass Pots at Nemours	Bohemian Glass Pots.	Glass Pots of Creusot.
Silica - - -	70·9	64·6	63·7	65·2	67·4	68·0	68·0
Alumina - -	24·8	34·4	20·7	25·0	32·0	29·0	28·0
Oxyde of Iron -	3·8	1·0	4·0	7·2	0·8	2·2	2·0
Magnesia - -	trace	–	–	trace	trace	0·5	trace
Water - - -	–	–	10·3*	–	–	–	1·0

Wurzer states the composition of the sand and clay in the Hessian crucibles as follows:—

Clay;	silica 10·1;	alumina 65·4;	oxydes of iron and manganese 1·2;	lime 0·3;	water 23
Sand;	95·6	2·1	1·5	0·8	

Black lead crucibles are made of two parts of graphite and one of fire clay; mixed with water into a paste, pressed in moulds, and well dried; but not baked hard in the kiln. They bear a higher heat than the Hessian crucibles, as well as sudden changes of temperature; have a smooth surface, and are therefore preferred by the melters of gold and silver. This compound forms excellent small or portable furnaces.

Mr. Anstey describes his patent process for making crucibles, as follows: Take two parts of fine ground raw Stourbridge clay, and one part of the hardest gas coke, previously pulverized, and sifted through a sieve of one eighth of an inch mesh (if the coke is ground too fine the pots are very apt to crack). Mix the ingredients together with the proper quantity of water, and tread the mass well. The pot is moulded by hand upon a wooden block, supported on a spindle which turns in a hole in the bench; there is a gauge to regulate the thickness of the melting pot, and a cap of linen or cotton placed wet upon the core before the clay is applied, to prevent the clay from sticking partially to the core, in the taking off; the cap adheres to the pot only while wet, and may be removed without trouble or hazard when dry. He employs a wooden bat to assist in moulding the pot; when moulded, it is carefully dried at a gentle heat. A pot dried as above, when wanted for use, is first warmed by the fire-side, and is then laid in the furnace with the mouth downwards (the red cokes being previously damped with cold ones in order to lessen the heat); more coke is then thrown in till the pot is covered, and it is now brought up gradually to a red heat. The pot is next turned and fixed in a proper position in the furnace, without being allowed to cool, and is then charged with cold iron, so that the metal, when melted, shall have its surface a little below the mouth of the pot. The iron is melted in about an hour and a half, and no flux or addition of any kind is made use of. A pot will last for fourteen or even eighteen successive meltings, provided it is not allowed to cool in the intervals; but if it cool, it will probably crack. These pots, it is said, can bear a greater heat than others without softening, and will, consequently, deliver the metal in a more fluid state than the best Birmingham pots will. See a figure of the crucible mould under Steel.

CRYSTAL is the geometrical form possessed by a vast number of mineral and saline substances; as also by many vegetable and animal products. The integrant particles of matter have undoubtedly determinate forms, and combine with one another, by the attraction of cohesion, according to certain laws, and points of polarity, whereby they assume a vast variety of secondary crystalline forms. The investigation of these laws belongs to crystallography, and is foreign to the practical purpose of this volume. Instructions are given under each object of manufacture which requires crystallization, how to conduct this process. See Borax, Salt, &c.

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* This crucible had been analyzed before being baked in the kiln.

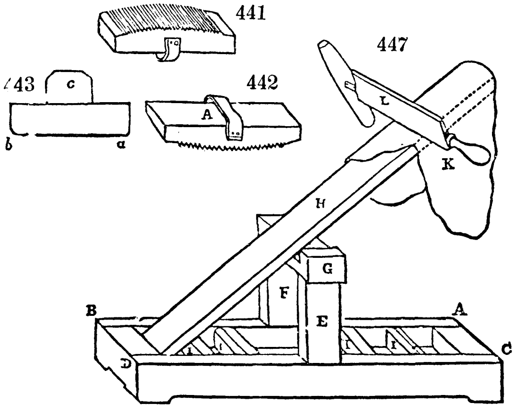
CUDBEAR was first made an article of trade in this country, by Dr. Cuthbert Gordon, from whom it derived its name, and was originally manufactured on a great scale by Mr. G. Mackintosh, at Glasgow, nearly 80 years ago. Cudbear or persio is a powder of a violet red color, difficult to moisten with water, and of a peculiar but not disagreeable odor. It is partially soluble in boiling water, becomes red with acids, and violet blue with alkalis. It is prepared in the same way as archil, only towards the end the substance is dried in the air, and is then ground to a fine powder, taking care to avoid decomposition, which renders it glutinous In Scotland they use the lichen tartareus, more rarely the lichen calcareus, and omphalodes; most of which lichens are imported from Sweden and Norway, under the name of rock moss. The lichen is suffered to ferment for a month, and is then stirred about to allow any stones which may be present to fall to the bottom. The red mass is next poured into a flat vessel, and left to evaporate till its urinous smell has disappeared, and till it has assumed an agreeable color verging upon violet. It is then ground to fine powder. During the fermentation of the lichen, it is watered with stale urine, or with an equivalent ammoniacal liquor of any kind, as in making archil.

CUPELLATION is a mode of analyzing gold, silver, palladium, and platinum, by adding to small portions of alloys, containing these metals, a bit of lead, fusing the mixture in a little *cup* of bone earth called a *cupel*, then by the joint action of heat and air, oxydizing the copper, tin, &c., present in the precious metals. The oxydes thus produced are dissolved and carried down into the porous *cupel* in a liquid state, by the vitrified oxyde of lead. See Assay, Gold, and Silver.

CURRYING OF LEATHER (*Corroyer*, Fr.; *Zurichten*, Germ.) is the art of dressing skins after they are tanned, for the purpose of the shoe-maker, coach and harness maker, &c., or of giving them the necessary smoothness, lustre, color, and suppleness. The currier's shop has no resemblance to the tanner's premises, having a quite different set of tools and manipulations.

The currier employs a strong hurdle about a yard square, made either of basket twigs, or of wooden spars, fixed rectangularly like trellis work, with holes 3 inches square, upon which he treads the leather, or beats it with a mallet or hammer, in order to soften it, and render it flexible.

The *head knife*, called in French *couteau à revers*, on account of the form of its edge, which is much turned over, is a tool 5 or 6 inches broad, and 15 or 16 long; with two handles, one in the direction of the blade, and the other perpendicular to it, for the purpose of guiding the edge more truly upon the skin. The pommel (*paumelle*) is so called because it clothes the palm of the hand, and performs its functions. It is made of hard wood, and is of a rectangular shape, 1 foot long, 5 inches broad, flat above and rounded below. It is furrowed over the rounded surface with transverse parallel straight grooves. These grooves are in section sharp-edged isosceles triangles. *Figs.* 441 and 442, represent the pommel in an upper and under view. The flat surface is provided with a leather strap for securing it to the hand of the workman. Pommels are made of different sizes, and with grooves of various degrees of fineness. Cork pommels are also used, but they are not grooved. Pommels serve to give grain and pliancy to the skins.

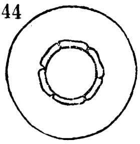


The *stretching iron*, *fig.* 443, is a flat plate of iron or copper, fully a fourth of an inch thick at top, and thinning off at bottom in a blunt edge, shaped like the arc of a circle of large diameter, having the angles *a* and *b* rounded, lest in working they should penetrate the leather. The top *c* is mounted with leather to prevent it from hurting the hands. A copper stretching knife is used for delicate skins. The workman holds this tool nearly perpendicular, and scrapes the thick places powerfully with his two hands, especially those where some tan or flesh remains. He thus equalizes the thickness of the skin, and renders it at the same time more dense and uniform in texture. This tool is of very general use in currying.

The round knife, *figs.* 444 and 445 (*lunette* in French), is a circular knife from 10 to 12 inches in diameter, with a round 4 or 5 inch hole in its centre, for introducing the hands and working it. It is concave, as shown in the section *fig.* 445, presenting the form of a spherical zone. The concave part is that applied to the skin. Its edge is not perfectly straight; but is a little turned over on the side opposite to the skin, to prevent it from entering too far into the leather. The currier first slopes off with the head knife from the edges, a portion equal to what he afterwards removes with the round one. By this division the work is done sooner and more exactly. All the oiled or greased skins are dressed with the round knife.

The *cleaner* is a straight two-handled knife two inches broad, of which there are two kinds, a sharp-edged and a blunt one. *Fig.* 446.

444



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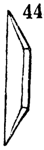

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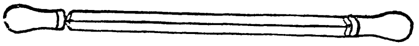

The *mace* is made of wood, having a handle 30 inches long, with a cubical head or mallet; upon the two faces of which, parallel to the line of the handle, there are 4 pegs of hard wood turned of an egg-shape, and well polished, so as not to tear the moistened leather when it is strongly beat and softened with the mace.

The horse or trestle, *fig.* 447, consists of a strong wooden frame, A B C D, which serves as a leg or foot. Upon the middle of this frame there are two uprights, E F, and a strong cross beam, G, for supporting the thick plank H, upon which the skins are worked. This plank may be set at a greater or less slope, according as its lower end is engaged in one or other of the cross bars, I I I I, of the frame. In the figure, a skin K is represented upon the plank with the head knife upon it, in the act of being pared.

A cylindrical bar fixed horizontally at its ends to two buttresses projecting from the wall, serves by means of a parallel stretched cord, to fix a skin by a coil or two in order to dress it. This is accordingly called the *dresser*. The tallow cloth is merely a mop made of stout rags, without the long handle; of which there are several, one for wax, another for oil, &c. Strong-toothed pincers with hook-end handles, drawn together by an endless cord, are employed to stretch the leather in any direction, while it is being dressed. The currier uses clamps like the letter U, to fix the edges of the leather to his table. His polisher is a round piece of hard wood, slightly convex below, with a handle standing upright in its upper surface, for seizing it firmly. He first rubs with sour beer, and finishes with barberry juice.

Every kind of tanned leather not intended for soles or such coarse purposes, is generally curried before being delivered to the workmen who fashion it, such as shoemakers, coachmakers, saddlers, &c. The chief operations of the currier are four:—

1. Dipping the leather, which consists in moistening it with water, and beating it with the *mace* or a mallet upon the hurdle. He next applies the *cleaners,* both blunt and sharp, as well as the head knife, to remove or thin down all inequalities. After the leather is shaved, it is thrown once more into water, and well scoured by rubbing the grain side with pumice stone, or a piece of slaty grit, whereby it parts with the bloom, a whitish matter, derived from the oak bark in the tan pit.

2. Applying the pommel to give the leather a granular appearance, and correspondent flexibility. The leather is first folded with its grain side in contact, and rubbed strongly with the pommel, then rubbed simply upon its grain side; whereby it becomes extremely flexible.

3. Scraping the leather. This makes it of uniform thickness. The workman holds the tool nearly perpendicular upon the leather, and forcibly scrapes the thick places with both his hands.

4. Dressing it by the round knife. For this purpose he stretches the leather upon the wooden cylinder, lays hold of the pendent under edge with the pincers attached to his girdle, and then with both hands applies the edge of the knife to the surface of the leather, slantingly from above downwards, and thus pares off the coarser fleshy parts of the skin. This operation requires great experience and dexterity; and when well performed improves greatly the look of the leather.

The hide or skin, being rendered flexible and uniform, is conveyed to the shed or drying house, where the greasy substances are applied, which is called dubbing (daubing) or stuffing. The oil used for this purpose is prepared by boiling sheep-skins or doe-skins, in cod oil. This application of grease is often made before the graining board or pommel is employed.

Before waxing, the leather is commonly colored by rubbing it with a brush dipped into a composition of oil and lamp black on the flesh side, till it be thoroughly black; it is then black-sized with a brush or sponge, dried, tallowed with the proper cloth, and slicked upon the flesh with a broad, smooth lump of glass; sized again with a sponge; and when dry, again curried as above described.

Currying leather on the hair or grain side, termed black on the grain, is the same in the first operation with that dressed on the flesh, till it is scoured. Then the first black is applied to it while wet, by a solution of copperas put upon the grain, after this has been rubbed with a stone; a brush dipped in stale urine is next rubbed on, then an iron slicker is used to make the grain come out as fine as possible. It is now stuffed with oil. When dry, it is seasoned; that is, rubbed over with a brush dipped in copperas water, on the grain, till it be perfectly black. It is next slicked with a good grit stone, to take out the wrinkles, and smooth the coarse grain. The grain is finally raised with the pommel or graining board, by applying it to the leather in different directions. When thoroughly dry, it is grained again in two or three ways.

Hides intended for covering coaches are shaved nearly as thin as shoe hides, and blacked upon the grain.

CUTLERY. (*Coutellerie*, Fr.; *Messerschmidwaare*, Germ.) Three kinds of steel are made use of in the manufacture of different articles of cutlery, viz., common steel, shear steel, and cast steel. Shear steel is exceedingly plastic and tough. All the edge tools which require great tenacity without great hardness are made of it, such as table knives, scythes, plane-irons, &c.

Cast steel is formed by melting blistered steel in covered crucibles, with bottle glass, and pouring it into cast-iron moulds, so as to form it into ingots; these ingots are then taken to the tilt, and drawn into rods of suitable dimensions. No other than cast steel can assume a very fine polish, and hence all the finer articles of cutlery are made of it, such as the best scissors, penknives, razors, &c.

Formerly cast steel could be worked only at a very low heat; it can now be made so as to be welded to iron with the greatest ease. Its use is consequently extended to making very superior kinds of chisels, plane-irons, &c.

Forging of table knives. — Two men are generally employed in the forging of table knives; one called the foreman or maker, and the other the striker.

The steel called common steel is employed in making the very common articles; but for the greatest part of table knives which require a surface free from flaws, shear steel is generally preferred. That part of the knife termed the blade, is first rudely formed and cut off. It is next welded to a rod of iron about ½ inch square, in such a manner as to leave as little of the iron part of the blade exposed as possible. A sufficient quantity of the iron now attached to the blade, is taken off from the rod to form the bolster or shoulder, and the tang.

In order to make the bolster of a given size, and to give it at the same time shape and neatness, it is introduced into a die, and a swage placed upon it; the swage has a few smart blows given it by the striker. This die and swage are, by the workman, called prints.

After the tangs and bolster are finished, the blade is heated a second time, and the foreman gives it its proper anvil finish; this operation is termed smithing. The blade is now heated red-hot, and plunged perpendicularly into cold water. By this means it becomes hardened. It requires to be tempered regularly down to a blue color: in which state it is ready for the grinder.

Mr. Brownill's method of securing the handles upon table-knives and forks, is, by lengthening the tangs, so as to pass them completely through the handle, the ends of which are to be tinned after the ordinary mode of tinning iron; and, when passed through the handle, the end of the tang is to be spread by beating, or a small hole drilled through it, and a pin passed to hold it upon the handle. After this, caps of metal, either copper plated or silver, are to be soldered on to the projecting end of the tang, and while the solder is in a fluid state, the cap is to be pressed upon the end of the handle and held there until the solder is fixed, when the whole is to be cooled by being immersed in cold water.

Mr. Thomason's patent improvements consist in the adaptation of steel edges to the blades of gold and silver knives. These steel edges are to be attached to the other metal, of whatever quality it may be, of which the knife, &c. is made, by means of solder, in the ordinary mode of effecting that process. After the edge of steel is thus attached to the gold, silver, &c., it is to be ground, polished, and tempered by immersion in cold water or oil after being heated. This process being finished, the other parts of the knife are then wrought and ornamented by the engraver or chaser, as usual.

A patent was obtained in 1827, by Mr. Smith of Sheffield, for rolling out knives at one operation.

In the ordinary mode of making knives, a sheet of steel being provided, the blades are cut out of the sheet, and the backs, shoulders, and tangs, of wrought iron, are attached to

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the steel blades, by welding at the forge. The knife is then ground to the proper shape, and the blade polished and hardened.

Instead of this welding process, the patentee proposes to make the knives entirely of steel, and to form them by rolling in a heated state between massive rollers; the shoulders or bolsters, and the tangs for the handles being produced by suitable recesses in the peripheries of the rollers; just as railway rails are formed. When the knife is to be made with what is called a scale tang, that is, a broad flat tang, to which the handle is to be attached in two pieces, riveted on the sides of the tang, the rollers are then only to have recesses cut in them, in a direction parallel to the axis for forming the bolster.

The plate of steel, having been heated, is to be pressed between the two rollers, by which the blades and the parts for the scale tangs will be pressed out flat and thin, and those parts which pass between the grooves or recess will be left thick or protuberant, forming the bolster for the shoulder of the blade. But if the tangs are to be round in order to be fixed into single handles, then it will be necessary also to form transverse grooves in the rollers, that is, at right angles to those which give shape to the bolsters, the transverse grooves corresponding in length to the length of the intended tang. When the plates of steel have been thus rolled, forming three or more knives in a breadth, the several knives are to be cut out by the ordinary mode of what is called slitting, and the blades and shoulders ground, hardened, and polished in the usual way.

Forks are generally a distinct branch of manufacture from that of knives, and are purchased of the fork makers by the manufacturers of table knives, in a state fit for receiving the handles.

The rods of steel from which the forks are made, are about ⅝ths of an inch square. The tang and shank of the fork are first roughly formed. The fork is then cut off, leaving at one end about 1 inch of the square part of the steel. This part is afterwards drawn out flat to about the length of the prongs. The shank and tang are now heated, and a proper form given to them by means of a die and swage. The prongs are afterwards formed at one blow by means of the stamp; this machine is very similar to that used in driving piles, but it is worked by one man. It consists of a large anvil fixed in a block of stone nearly on a level with the ground. To this anvil are attached two rods of iron of considerable thickness, fixed twelve inches asunder, perpendicularly to the anvil, and diagonally to each other. These are fastened to the ceiling. The hammer or stamp, about 100 lbs. in weight, having a groove upon either side corresponding to the angles of the upright rods, is made to slide freely through its limited range, being conducted by its two iron supporters. A rope is attached to the hammer, which goes over a pulley on the floor of the room above, and comes down to the person who works the stamp: two corresponding dies are attached, one to the hammer, and the other to the anvil. That part of the fork intended to form the prongs, is heated to a pretty white heat and placed in the lower die, and the hammer containing the other die is made to fall upon it from a height of about 7 or 8 feet. This forms the prongs and the middle part of the fork, leaving a very thin substance of steel between each prong, which is afterwards cut out with an appropriate instrument called a fly-press. The forks are now annealed by surrounding a large mass of them with hot coals, so that the whole shall become red-hot. The fire is suffered gradually to die out, and the forks to cool without being disturbed. This process is intended to soften, and by that means to prepare them for filing. The inside of the prongs is then filed, after which they are bent into their proper form and hardened. When hardened, which is effected by heating them red-hot and plunging them into cold water, they are tempered by exposing them to the degree of heat at which grease inflames. See STAMPS.

Penknives are generally forged by a single hand, with the hammer and the anvil simply. The hammer in this trade is generally light, not exceeding 3½ lbs. The breadth of the face, or the striking part, is about one inch; if broader, it would not be convenient for striking so small an object. The principal anvil is about 5 inches, and 10 upon the face, and is provided with a groove into which a smaller anvil is wedged. The smaller anvil is about 2 inches square upon the face. The blade of the knife is first drawn out at the end of the rod of steel, and as much more is cut off along with it as is thought necessary to form the joint. The blade is then taken in a pair of tongs, and heated a second time to finish the joint part, and at the same time to form a temporary tang for the purpose of driving into a small haft used by the grinder. Another heat is taken to give the blade a proper finish. The small recess called the nail-hole, used in opening the knife, is made while it is still hot by means of a chisel, which is round on one side, and flat upon the other.

Penknives are hardened by heating the blade red-hot, and dipping them into water up to the shoulder. They are tempered by setting them side by side, with the back downwards upon a flat iron plate laid upon the fire, where they are allowed to remain till they are of a brown or purple color.

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The blades of pocket knives, and all that come under the denomination of spring knives, are made in the same way.

The forging of razors is performed by a foreman and striker, as in making table knives.

They are generally made of cast steel. The rods, as they come from the tilt, are about ½ inch broad, and of a thickness sufficient for the back of a razor.

There is nothing peculiar in the tools made use of in forging razors: the anvil is a little rounded at the sides, which affords the opportunity of making the edge thinner, and saves an immense labor to the grinder.

Razors are hardened and tempered in a similar manner to penknives. They are, however, left harder, being only let down to yellow or brown color.

The forging of scissors is wholly performed by the hammer, and all the sizes are made by a single hand. The anvil of the scissor-maker weighs about 1½ cwt.; it measures, on the face, about 4 by 11 inches. It is provided with two grates or grooves for the reception of various little indented tools termed by the workman bosses; one of these bosses is employed to give proper figure to the shank of the scissors; another for forming that part which has to make the joint; and a third is made use of for giving a proper figure to the upper side of the blade. There is also another anvil placed on the same block, containing two or three tools called beak-irons, each consisting of an upright stem about 6 inches high, at the top of which a horizontal beak projects; one of these beaks is conical, and is used for extending the bow of the scissors; the other is a segment of a cylinder with the round side upwards, containing a recess for giving a proper shape and smoothness to the inside of the bow.

The shank of the scissors is first formed by means of one of the bosses, above described, leaving as much steel at the end as will form the blade. A hole is then punched about ¼ inch in width, a little above the shank. The blade is drawn out and finished, and the scissors separated from the rod a little above the hole. It is heated a third time, and the small hole above mentioned is extended upon the beak-irons so as to form the bow. This finishes the forging of scissors. They are promiscuously made in this way, without any other guide than the eye, having no regard to their being in pairs. They are next annealed for the purpose of filing such parts of them as cannot be ground, and afterwards paired.

The very large scissors are made partly of iron, the blades being of steel.

After the forging, the bow and joints, and such shanks as cannot be ground, are filed. The rivet hole is then bored, through which they are to be screwed or riveted together. This common kind of scissors is only hardened up to the joint. They are tempered down to a purple or blue color. In this state they are taken to the grinder.

Grinding and polishing of cutlery.—The various processes which come under this denomination are performed by machinery, moving in general by the power of the steam-engine or water-wheel.

Grinding wheels or grinding mills are divided into a number of separate rooms; every room contains six places called troughs; each trough consists of a convenience for running a grindstone and a polisher at the same time, which is generally occupied by a man and a boy.

The business of the grinder is generally divided into three stages, viz., grinding, glazing, and polishing.

The grinding is performed upon stones of various qualities and sizes, depending on the articles to be ground. Those exposing much flat surface, such as saws, fenders, &c., require stones of great diameter, while razors, whose surface is concave, require to be ground upon stones of very small dimensions. Those articles which require a certain temper, which is the case with most cutting instruments, are mostly ground on a wet stone; for which purpose the stone hangs within the iron trough, filled with water to such a height that its surface may just touch the face of the stone.

Glazing is a process following that of grinding: it consists in giving that degree of lustre and smoothness to an article which can be effected by means of emery of the various degrees of fineness. The tool on which the glazing is performed, is termed a glazer. It consists of a circular piece of wood, formed of a number of pieces in such a manner that its edge or face may always present the endway of the wood. Were it made otherwise, the contraction of the parts would destroy its circular figure. It is fixed upon an iron axis similar to that of the stone. Some glazers are covered on the face with leather, others with metal, consisting of an alloy of lead and tin; the latter are termed caps. In others, the wooden surface above is made use of. Some of the leather-faced glazers, such as are used for forks, table knives, edge tools, and all the coarser polished articles, are first coated with a solution of glue, and then covered with emery. The surfaces of the others are prepared for use by first turning the face very true, then filling it with small notches by means of a sharp-ended hammer, and lastly filling up the interstices with a compound of tallow and emery.

The pulley of the glazer is so much less than that of the stone, that its velocity is more than double, having in general a surface-speed of 1,500 feet in a second.

The process of polishing consists in giving the most perfect polish to the different articles. Nothing is subjected to this operation but what is made of cast steel, and has been previously hardened and tempered.

The polisher consists of a circular piece of wood covered with buff leather, the surface of which is covered from time to time, while in use, with the crocus of iron, called also colcothar of vitriol.

The polisher requires to run at a speed much short of that of the stone, or the glazer. Whatever may be its diameter, the surface must not move at a rate exceeding 70 or 80 feet in a second.

CYANATES; saline compounds of cyanic acid with the bases potash, soda, ammonia, baryta, &c. The first is prepared by calcining at a dull red heat, a mixture of ferro-cyanide of potassium (prussiate of potash) and black oxide of manganese. The cyanates have not hitherto been applied to any use in the arts.

CYANHYDRIC ACID; another name for the hydrocyanic or prussic acid. See Prussian Blue and Prussic Acid.

CYANIDES; compounds of cyanogen with the metals; as cyanide of potassium, sodium, barium, calcium, iron, mercury. The last is the only one of importance in a manufacturing point of view, since from it prussic acid is often made.

CYANIDES, FERRO. Double compounds of cyanogen with iron, and of cyanogen with another metal, such as potassium, sodium, barium, &c. The ordinary yellow prussiate of potash has this constitution, and is called the ferro-cyanide.

CYANIDE OF POTASSIUM. This salt, so much used now in the electrotype processes, is prepared, according to Liebig's formula, by mixing 8 parts of pounded prussiate of potash, sharply dried, with 3 parts of pure carbonate of potash, fusing the mixture in an iron crucible, by a moderate red heat, and keeping it so, till the glass or iron rod with which the fluid mass should be occasionally stirred, comes out covered with a white crust. The crucible is then to be removed from the fire; and after the disengaged iron has fallen to the bottom, the supernatant fluid, still obscurely red hot, is to be poured off upon a clean surface of iron or platinum. After concretion and cooling, the white saline mass is to be pounded while hot, and then kept in a well-stopped bottle. It consists of about only 60 per cent. of cyanide of potassium, and 1 of cyanate of potash. For most purposes, and the analysis of ores, the latter ingredient is no ways detrimental. It contains much of other potash salts.

CYANOGEN. A gaseous compound of two prime equivalents of charcoal = 12, and one of azote = 14 = 26; hydrogen being the radix, or 1. It consists of two volumes of vapor of carbon, and one volume of azote, condensed into one volume; and has therefore a density equal to the sum of the weights of these three gaseous volumes = 1·815. Cyanogen is readily procured by exposing the cyanide of mercury to a dull red heat in a retort; the gas is evolved and may be collected over mercury. Its smell is very sharp and penetrating; it perceptibly reddens tincture of litmus; it is condensable by pressure at a low temperature into a liquid; and by a still greater degree of cold, it is solidified. When a lighted taper is applied to a mixture of cyanogen and oxygen, an explosion takes place; carbonic acid is formed, and the azote is set at liberty.

For a connected view of the various compounds of cyanogen employed in the arts, see Prussian Blue.

CIDER (*Cidre*, Fr.; *Apfelwein*, Germ.); the vinous fermented juice of the apple. The ancients were acquainted with cider and perry, as we learn from the following passage of Pliny the naturalist: "Wine is made from the Syrian pod, from pears and apples of every kind." Book xiv. chap. 19. The term cider or cidre in French, at first written *sidre*, is derived from the Latin word *sicera*, which denoted all other fermented liquors except grape wine. Cider seems to have been brought into Normandy by the Moors of Biscay, who had preserved the use of it after coming into that country from Africa. It was afterwards spread through some other provinces of France, whence it was introduced into England, Germany, and Russia. It is supposed that the first growths of Normandy afford still the best specimens of cider. Devonshire and Herefordshire are the counties of England most famous for this beverage.

Strong and somewhat elevated ground, rather dry, and not exposed to the air of the sea, or to high winds, are the best situations for the growth of the cider apple. The fruit should be gathered in dry weather. The juice of apples is composed of a great deal of water; a little sugar analogous to that of the grape; a matter capable of causing fermentation with contact of air; a pretty large proportion of mucilage, with malic acid, acetic acid, and an azotized matter in a very small quantity. The seeds contain a bitter substance and a little essential oil; the pure parenchyma or cellular membrane constitutes

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not more than two per cent. of the whole. After the apples are gathered, they are left in the barn-loft for fifteen days or upwards to mellow; some of them in this case, however, become soft and brown. This degree of maturation diminishes their mucilage, and develops alcohol and carbonic acid; in consequence of which the cider suffers no injury. There is always, however, a little loss; and if this ripening goes a little further it is very apt to do harm, notwithstanding the vulgar prejudice of the country people to the contrary. Too much care, indeed, cannot be taken to separate the sound from the spoiled apples; for the latter merely furnish an acid leaven, give a disagreeable taste to the juice, and hinder the cider from fining, by leaving in it a certain portion of the parenchyma, which the gelatinous matter or the fermentation has diffused through it. Unripe apples should be separated from the ripe also, for they possess too little saccharum to be properly susceptible of the vinous fermentation.

In France, where cider-making is most scientifically practised, it is prepared by crushing the apples in a mill with revolving edge-stones, turned in a circular stone cistern by one or two horses. When the fruit is half mashed, about one fifth of its weight of river water is added, or the water of lakes. The latter has been found by experience to be preferable to other water.

In some places a mill composed of two cast-iron fluted cylinders, placed parallel to each other under the bottom of a hopper, is employed for crushing the apples. One of the cylinders is turned by a winch, and communicates its motion in the opposite direction by means of the flutings working into each other. Each portion of the fruit must be passed thrice through this rude mill in order to be sufficiently mashed; and the same quantity of water must be added as in the edge stone mill.

After the apples are crushed they are usually put into a large tub or tun for 12 or 24 hours. This steeping aids the separation of the juice, because the fermentative motion which takes place in the mass breaks down the cellular membranes; but there is always a loss of alcohol carried off by the carbonic acid disengaged, while the skins and seeds develop a disagreeable taste in the liquid. The vatting might be suppressed if the apples were so comminuted as to give out their juice more readily. With slight modifications, the process employed in rasping and squeezing the beet-roots might in my opinion be applied with great advantage to the cider manufacture. See SUGAR.

After the vatting, the mashed fruit is carried to the press and put upon a square wicker frame or into a hair bag, sometimes between layers of straw, and exposed stratum super stratum to strong pressure till what is called a cheese or cake is formed. The mass is to be allowed to drain for some time before applying pressure, which ought to be very gradually increased. The juice which exudes with the least pressure affords the best cider; that which flows towards the end acquires a disagreeable taste from the seeds and the skins. The must is put into casks with large bungholes, where it soon begins to exhibit a tumultuous fermentation. The cask must be completely filled, in order that all the light bodies suspended in the liquid when floated to the top by the carbonic acid may flow over with the froth; this means of clearing cider is particularly necessary with the weak kinds, because it cannot be expected that these matters in suspension will fall to the bottom of the casks after the motion has ceased. In almost every circumstance besides, when no saccharine matter has been added to the must, that kind of yeast which rises to the top must be separated, lest by precipitation it may excite an acid fermentation in the cider. The casks are raised upon gawntrees or stillions, in order to place flat tubs below them to receive the liquor which flows over with the froth. At the end of two or three days, for weak ciders which are to be drunk somewhat sweet, of 6 or 10 days or more for stronger ciders, with variations for the state of the weather, the fermentation will be sufficiently advanced, and the cider may be racked off into other casks.. Spirit puncheons preserve cider better than any other, but in all cases the casks should be well seasoned and washed. Sometimes a sulphur match is burned in them before introducing the cider, a precaution to be generally recommended, as it suspends the activity of the fermentation, and prevents the formation of vinegar.

The cider procured by the first expression is called cider without water. The cake remaining in the press is taken out, divided into small pieces, and mashed anew, adding about half the weight of water, when the whole is carried back to the press and treated as above described. The liquor thus obtained furnishes a weaker cider which will not keep, and therefore must be drunk soon.

The cake is once more mashed up with water, and squeezed, when it yields a liquor which may be used instead of water for moistening fresh ground apples.

The processes above described, although they have been long practised, and have therefore the stamp of ancestral wisdom, are extremely defective. Were the apples ground with a proper rotatory rasp which would tear all their cells asunder, and the mash put through the hydraulic press in bags between hurdles of wicker-work, the juice would be obtained in a state of perfection fit to make a cider superior to many wines

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An experimental process of this kind has been actually executed in France upon a considerable scale, with the best results. The juice had the fine flavor of the apple, was fermented by itself without any previous fermentation in the mash, and afforded an excellent strong cider, which kept well.

When the must of the apples is weak or sour, good cider cannot be made from it without the addition of some saccharine matter. The syrup into which potato farina is convertible by *diastase* (saccharine ferment), see STARCH and SUGAR, would answer well for enriching poor apple-juice.

The value of apples to produce this beverage of good quality is proportionate to the specific gravity of their juice. M. Couverchel has given the following table, illustrative of that proposition.—

Juice of the green renette, queen apple (*reinette verte*)	1094
English renette	1080
Red renette	1072
Musk renette	1069
Fouillet rayé	1064
Orange apple	1063
Renette of Caux	1060
Water	1000

Cider apples may be distributed into three classes—the sweet, the bitter, and the sour. The second are the best; they afford a denser juice, richer in sugar, which clarifies well, and when fermented keeps a long time; the juice of sweet apples is difficult to clarify; but that of the sour ones makes bad cider. Late apples are in general to be preferred. With regard to the proper soil for raising apple-trees, the reader may consult with advantage an able essay upon "The Cultivation of Orchards and the making of Cider and Perry," by Frederick Falkner, Esq., in the fourth volume of the Royal Agricultural Journal. He adverts judiciously to the necessity of the presence of alkaline and earthy bases in the soils of all deciduous trees, and especially of such as produce acid fruits.

In November, 2340 kilogrammes of apples (2⅜ tons English, nearly) are supposed to afford 1000 litres (220½ gallons) of pure cider; and 600 litres of a small cider made with the marc mixed with water and pressed. But many persons mix all together, and thus manufacture 1600 litres out of the above weight of fruit. In France, the fermented liquor, as soon as it is clear, is often racked off into casks containing the fumes of burning sulphur, whereby it ceases to ferment, and preserves much of its sugar undecomposed. It is soon afterwards bottled. Average cider should yield 6 per cent. of alcohol on distillation.

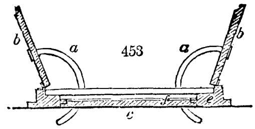
D.

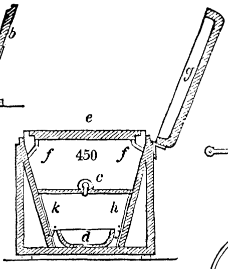
DAGUERREOTYPE. This new and most ingenious invention, for producing pictures by the action of light, is due to M. Daguerre and M. Niepce, two Frenchmen. It was purchased from them by the French government for the benefit of the nation at large; but was made the subject of an exclusive patent in this country by M. Daguerre, as our government never purchases any scientific invention.

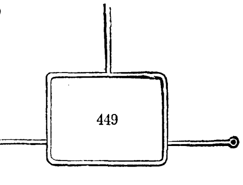
The fixation of the images, formed in the focus of the camera obscura, is made on very smooth surfaces of pure silver plated on copper. The process is divided into five operations. 1. The first consists in polishing and cleaning the silver surface, by friction with cotton fleece imbued with olive oil, upon the plate, previously dusted over with very finely-ground dry pumice-stone out of a muslin bag. The hand of the operator should be moved round in circles, of various dimensions. The plates should be laid upon a sheet of paper solidly supported. The pumice must be ground to an impalpable powder upon a porphyry slab with water, and then dried. The surface is next to be rubbed with a dossil of cotton, slightly moistened with nitric acid, diluted with sixteen parts of water, by applying the tuft to the mouth of the phial of acid, and inverting it for a moment. Two or three such dossils should be used in succession. The plate is lastly to be sprinkled with pumice powder or Venetian tripoli, and rubbed clean with cotton.

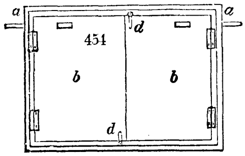
The next step is to heat the plate by placing it in a wire frame (*fig.* 449), with the silver surface uppermost, over a spirit lamp, meanwhile moving it so as to act equally on every part of the plate. In about five minutes a whitish coating will indicate that this operation is completed. The plate must now be laid upon a flat metal or marble slab to cool it quickly. The white surface is to be brightened by rubbing it with cotton and pumice powder. It must be once more rubbed with the cotton imbued with acid, and afterward dried by friction with cotton and pumice; avoiding to touch the plate with the fingers, or with the part of the cotton held in them, or to breathe upon the plate, since spots would thereby be produced. After cleaning with cotton alone, the plate is ready for the next operation.

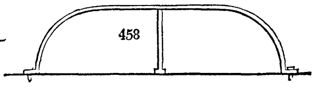
2. Here the following implements are required: 1, the box represented in *figs.* 450 and 451; 2, the thin board or frame, *fig.* 452; four small metallic bands of the same











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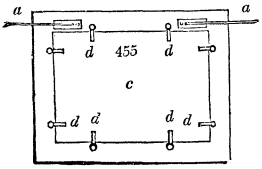

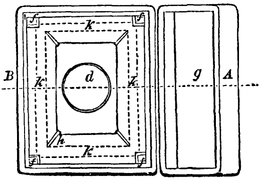

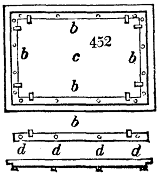

metals as the plates, also shown in *fig*, 452, a small handle and a box of small nails or tacks, and a phial of iodine.

After fixing, by the metallic bands and the small nails, the plate upon the thin board, with the silver uppermost, several particles of iodine are then to be spread in the dish *d*, at the bottom of the box, *figs*. 450, and 451. The thin board with the plate, is next placed, with the silver *beneath*, upon small supports at the four corners of the box, and its cover is applied. The plate must be left in this position till the surface of the silver acquires a fine golden hue, caused by the vapors of the iodine rising through the gauze cover of the dish, and condensing upon it; but it should not be allowed to assume a violet tint. The room should be darkened, and no heat should be employed. When the box is in constant use it gets impregnated with iodine, and acts more uniformly and rapidly; but in general states of the atmospheric temperature this operation will be effected in about twenty minutes. If the purple color be produced, the plate must be repolished, and the whole process repeated.

The plate with its golden hue is to be introduced with its board into the frame, *figs*. 453, 454, 455, which is adapted to the camera obscura. During this transfer the light must not be suffered to strike upon the surface of the plate; on which account, the camera obscura may be lighted briefly with a small wax taper.

3. The plate is now submitted to the third operation, that of the camera obscura, *figs*. 456 and 448, and with the least possible delay. The action of this machine is obviously quicker the brighter the light which acts upon it; and more correct, according as the focus is previously accurately adjusted to the place of the plate, by moving backwards and forwards a roughened pane of glass, till the focal point be found; and the plate is to be inserted precisely there, see *figs*. 453, 454, 455. This apparatus exactly replaces the ground glass. While the prepared plate is being fastened, the camera must be closed. The darkening shutters, *b b*, of the apparatus are opened by means of the two semicircles, *a a*. The plate is now in a proper position to receive and retain the impression of the image of the objects presented the moment that the camera is opened. Experience alone can teach the proper length of time for submitting the plate to the concentrated rays of light; because that time varies with the climate, the seasons, and the time of day. More time should not be allowed to pass than what is necessary for fixing a distinct impression, because the parts meant to be clear would be apt to become clouded.

4. The fourth is the operation with quicksilver, which must follow as soon as possible the completion of the third. Here a phial of quicksilver, a spirit-lamp (the apparatus represented in *figs*. 457 and 458), and a glass funnel with a long neck, are required. The funnel is used for pouring the mercury into the cup *c*, placed in the

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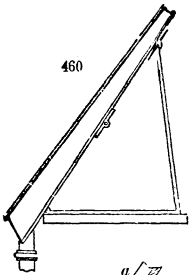
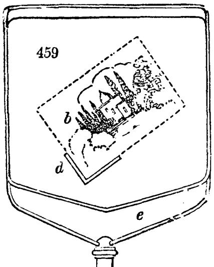
bottom of the apparatus, so as to cover the bulb of the thermometer *f*. No daylight must now be admitted, but that of a small taper only should be used by the operator in conducting the process. The board with the plate is to be withdrawn from the camera, and inserted into the grooves of the blackened board, *b*, *fig.* 457. This black board is laid back into the box at an angle of 45° with the horizon; the prepared metal surface *h* being placed undermost, so that it may be viewed through the side glass *g;* and the cover, *a*, of the box must be put down gently, to prevent any particles of mercury from being thrown about by the agitation of the air. The whole being thus prepared, the spirit-lamp is lighted, and placed under the cup containing the mercury, and left there until the thermometer indicates a temperature of 140° Fahr., when the lamp is to be removed. The heat should in no case be permitted to exceed 167° F.

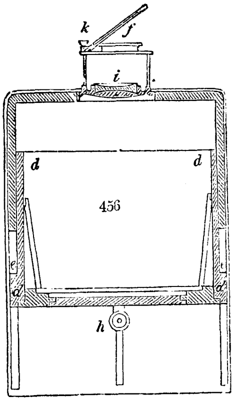
460



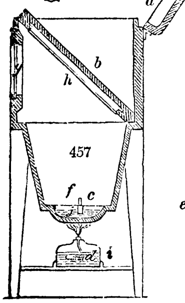
459



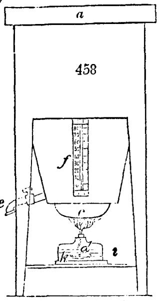
456



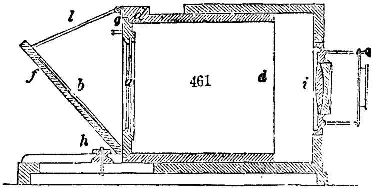
457



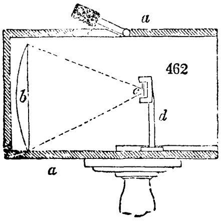
458



461



462



463

The impression of the image of nature is now actually made upon the plate; but it is yet invisible; and it is only after a lapse of several minutes that faint tracings of the objects begin to be seen through the peep-glass by the momentary gleam of a taper. The plate should be left in the box till the thermometer has cooled to 113° F., when it is to be taken out.

After each operation, the interior of the apparatus, and the black board or frame, should be carefully wiped, in order to remove every particle of mercury.

The picture may now be inspected in a feeble light, to see how far the process has succeeded. The plate, freed from the metallic bands, is to be placed in a box, provided with a cover and grooves, to exclude the light, till it is made to undergo the fifth and last operation, which may be done after any convenient interval of time without detriment, provided the plate be kept in the dark. The following articles are now required: 1, strong brine, or a weak solution of hyposulphate of soda; 2, the apparatus represented in *figs.* 459 and 460; 3, two troughs of tin-plate; 4, a jug of distilled water. The object of this process is to fix the photogenic picture. One of the troughs is to be filled with brine to the depth of an inch, and the other with pure water, both liquids being heated somewhat under the boiling pitch. The solution of hyposulphite of soda is preferable, and does not need to be warm. The plate is to be first immersed in the pure water for a moment, and transferred immediately to the saline solution, and moved to and fro in it to equalize the action of the liquor. Whenever the yellow tint of the iodine is removed, the plate is to be lifted out by the edges, and dipped straightway in the water-trough. The apparatus of *figs.* 459, and 460, is then brought into use, with a vessel filled with distilled water, hot, but not boiling. The plate, when lifted out of the water-trough, is to be placed immediately on the inclined plane *e*; and without allowing it time to dry, is to be floated over with the hot distilled water from the top, so as to carry off all the saline matter. As the quicksilver which traces the images will not bear touching, the silvered plate should be secured by a cover of glass, made tight at the edges by pasting paper round them.

In *fig.* 451, which is a plan view of the iodine-box apparatus, *c* is an interior cover; *d* is the iodine-dish; *e* is the thin board to which the silvered plate is fixed, as shown at *fig.* 450; *g* is the cover of the box; *h h* are small rods, at the four corners of the inclined lining, *k*, of the box, to support the lid *c*; *j* is a gauze of wire-cloth cover, to diffuse the iodine vapor; *k* is the wooden lining, sloping like a hopper; *d d*, in *fig.* 454, are buttons to fasten the board on the doors; *e* shows the thickness of the frame; *f* is the silvered plate. In *fig.* 461, *a* is the ground glass of the camera; *b* is a mirror inclined about 45° to the horizon, by means of the rod *l*. The image of the object is easily brought into focus by moving forward or backward the sliding-box *d*, in laying hold of it with both hands by the projections *a*, *fig.* 454. When the focus is adjusted, the thumbscrew, *h*, fixes the whole. The mirror is kept closed by two hooks at *f*, which take into small eyes at *g*. The frame and ground glass plate are withdrawn and replaced by the frame carrying the prepared plate, as represented in *fig.* 448, with the shading doors, *b*, open in the camera. These doors and the sliding-box *d* are lined with black velvet. The object glass is achromatic and periscopic, the concave being outside in the camera; its diameter is about 3½ inches, and focus about 13 inches. A diaphragm is placed before the object glass, at 3½ inches from it, and its aperture may be closed by a plate moving in a pivot. This camera reverses the objects from left to right; but this may be obviated by placing a plane mirror on the outside beyond the aperture of the diaphragm, as at *f*, *fig.* 456, where it is fixed by means of a screw, *k*. Loss of light is thereby occasioned.

Fig. 457 is an upright section, and *fig.* 458, a front elevation of the mercurial apparatus. *a*, the cover; *b*, the black board, with grooves to receive the board, *h*; *c*, the cup of quicksilver; *d*, the spirit-lamp; *e*, a small cock, through which the quicksilver may be run off, if the apparatus be laid to one side; *f*, the thermometer; *g*, a glass window; *h*, the board bearing the metallic plate; *l*, a stand for the spirit-lamp, which is held by the ring *k*, so that its flame may strike the bottom of the cup. The whole of the inside of the apparatus should be blackened and varnished.

Fig. 459 is a front view of the washing apparatus made of tin plate, varnished. The plates, to be washed, are laid on the angular ledge, *d*; *e* is a ledge to conduct the water to the receptacle *c*. *Fig.* 460 is a side view of the washing apparatus. The patent was enrolled in February, 1840. (See *Newton's Journal*, C. S. xvi., 1.)

Mr. Richard Beard having purchased from M. Daguerre a license to practise his invention above described, received from a foreigner a communication of certain improvements, for which he obtained a patent in June, 1840. The first of these is the substitution of a concave reflecting mirror for the lens in the camera obscura. *Fig.* 462 represents in section a slight wooden box, *a a*, open at the front, opposite to the person sitting for the portrait. In the back part of the box a concave mirror, *b*, is placed, to reflect the rays coming from the person. A small frame, *c*, is fixed to an adjustable pedestal, *d*, which slides in grooves in the bottom of the box, for the purpose of being set at the focal point of the mirror. In this frame, *c*, a polished surface is first to be placed for trial, to receive the image correctly, as observed by the operator, by looking through the opening, *e*, in the top of the box. The prepared silvered plate is now substituted in the exact place for the trial one. The luminous impression being made, the slide, *d*, is withdrawn, and the plate removed; carefully shut up in a box from the light.

The second object of this patent is making the prepared surface more uniform, by passing two plates, with their silvered faces in contact, several times between hardened rollers, annealing them at a low red heat after each passage.

His third object is to use a compound of bromine and iodine, instead of the latter alone, for coating the silver; which increases its sensibility to light, thereby shortening and improving the operation of taking likenesses. He also recommends to use a combination of iodine with nitric acid. Finally, Mr. Beard finds that by placing a screen of any desired color behind the sitter, the appearance of his Daguerreotype portrait is improved. (*Newton's Journal*, xxiii., 112.)

M. A. J. F. Claudet, who had also purchased a license from M. Daguerre, obtained a patent in December, 1841, for certain improvements upon the original process. His first object is to give the front of the camera obscura such an aperture as to admit the largest object-glass intended to be used; and of such he provides a series of different dimensions, each attached to its board, that may be fitted by a slide to the front of the camera.

One of the greatest difficulties in the Daguerrotype process was the impossibility of ascertaining the precise moment at which the light had produced, on the prepared plate, the effect requisite for the vapor of mercury to bring out the image. By applying that vapor to the plate while the silver surface is being acted upon by the light, the operator is enabled to see when his picture is complete. Another advantage of this joint operation is, that the effect of the mercury upon those parts of the plate which have been acted upon by the light, are more perfect when caused to take place immediately under the luminous influence. Hence, instead of using the distinct box with the cup of quicksilver, he places a cup containing that metal in the camera obscura, with its spirit-lamp, and exhales the vapors there. When the mercury has risen to the proper temperature, the aperture of the object-glass is thrown open, and the light, reflected from the object to be delineated, is allowed to operate.

He watches the effect through an opening in the side of the camera, where he views the prepared plate by the light of a lantern passing through a piece of red or orange-colored glass in the (other) side of the camera. Whenever the light and mercury, by their simultaneous action, have produced a good image, the object-glass is covered, and the silver plate, with its picture, removed, in order to be washed and finished. M. Claudet embellishes his Daguerrotype portraits by placing behind the sitter screens of painted scenery, which furnish pleasing back grounds. He specifies also various kinds of artificial illumination, to be used in the absence of solar light. (*Newton's Journal*, C. S. xx. 430.)

According to M. Barnard, Daguerre's iodized plate should be exposed for half a minute to the action of chlorine, mixed with a large proportion of common air; whereby it becomes so sensitive, that the pictorial impression is produced in the short space of time necessary for removing and replacing the screen of the camera. The mercury is afterward employed; as also the hyposulphite wash. Daguerrotype pictures are colored by dusting over them powders of proper hues, which are immediately washed by passing the plate through water. What remains of the color after this ablution does not seem in the least to injure the appearance or alter the form of the image. It would seem that those parts of the picture which were at first black, retain, after being washed, a larger proportion of the coloring matter than the lighter parts.

Several valuable improvements seem to have been made in Vienna upon the Daguerrotype process; and among others, the mode of using *chloriodine.*

The best form of box for applying the chloriodic vapor is square, with its bottom of plate glass, supported a little above the table by feet, a thumb-screw being one of them, in order to give a certain inclination to the glass plate for spreading the chloriodine over it uniformly. A sheet of white paper being laid beneath the box, enables the operator to see whether the liquid chloriodine is properly distributed. There is a groove round the top of the box, into which the ledge of the lid fits tight. A thermometer is placed in the box.

Voigtland's lenses consist of two achromatic object-glasses placed apart; the first nearest the object, having an aperture of 18 lines; the second one of 19 lines; the solar focus of the two is 5¼ inches. A system of lenses of so short a focus with so large apertures affords from 11 to 12 times more illumination than Daguerre's original apparatus did. The finest portraits can be produced in the course of from 10 to 30 seconds with this arrangement. Such an apparatus, elegantly made in brass, costs only 120 gulden, or about 10 guineas.

Voigtland has recently made a camera with two object-glasses, as above arranged, each having an aperture of 37 lines, and a combined focus of 12 inches. By means of this instrument, portraits 5¼ inches in size can be made. The landscapes produced in them are very beautiful. Its price is 144 gulden, about 12 guineas. Along with the above apparatus, a box with a bottom of amalgamated copper is used for applying the vapor of mercury.

By peculiar methods of polishing the silvered copper plate, peculiar tones and tints may be given to the picture. The olive-oil and pumice-powder are indispensable for removing the scratches from the plate and to render its surface uniform. If a delicate blue tone be desired, the plate should be a second time polished with sulphuric ether and washed tripoli; and a third time with dilute nitric acid and Paris red, rubbing the plate lastly with a peace of washleather and crocus. But if a brownish black tone be wished for, a like series of operations is to be gone through, only instead of the ether and tripoli, spirit of ammonia and Vienna lime is to be used.

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To give the plate the utmost sensibility to light, a film of iodine should be given in the first place. If with dry iodine, this should be strewed, then covered with cotton, and lastly with a sheet of paper, and the plate above the last, but not so as to touch it This may be done also with a solution of 1 part of iodine in 6 of spirits of wine, pu into a saucer, which is laid on the bottom of the box, and covered with gauze. The plate is to be removed whenever it has acquired a faint brazen tint. By this means the plate receives the impressions of light so well as to produce good contrasts between the white and the dark places. The application of bromine afterward causes a rapid reception of the image, and occasions the deep black shades of an object. The best form is *brome* water, made by dissolving the bromine in a little distilled water, and then adding more, when it is wanted, till the solution acquires a straw-yellow color. A delicate thermometer being put into the box, the solution is to be spread uniformly on its glass bottom, the plate being laid on above and covered up, while the time of exposure must be counted by seconds, with a clock or watch. If the temperature be

41° F., the time should be 258 seconds.
50° ——— 230 —
59° ——— 201 —
68° ——— 158 —
77° ——— 113 —

By attending to these instructions, exact results may be always obtained.

A second mode of experimenting is with bromiodine; prepared by dissolving 1 part of bromine in an alcoholic solution of 5 parts of iodine; and diluting this mixture with water, till it acquires the color of Bavarian beer. The action of this application upon the plate is so rapid as hardly to leave time for consideration. It must be watched every instant till the dark gold yellow tint appear, when it is ready for the camera.

The best time of day for Daguerrotype operations is from an hour after the sun rises till he comes within 45° of the meridian, and not again till he has passed the meridian by 45°. When the sitting is too long, the parts which should be pure white become of a dirty blue tint, and the dark parts become brown. The picture is burnt, so to speak.

Chloride of gold applied to the picture has the effect of fixing and enlivening the tints. A small grate being fixed by a clamp to the edge of a table, the plate is laid upon it with the image uppermost, and overspread evenly with solution of chloride of gold, by means of a fine broad camel-hair brush, without letting any drop over the edge. A spirit lamp is now brought under the plate, and moved to and fro till a number of small steam bubbles appear upon the image. The spirit lamp must be immediately withdrawn. The remainder of the chloride solution must be poured back into the phial, to be used on another occasion. It is lastly to be washed and examined. This operation has been repeated three or four times with the happiest effect, of giving fixity and force to the picture. It may then be wiped with cotton without injury.

By dusting various pigment powders from small cotton-wool dossils upon the picture, previously coated with an alcoholic solution of copal, and nearly dry, the appearance of a colored miniature has been very successfully imitated. The varnish must be applied delicately with one stroke of a broad brush of badger hair.*

DAGUERREOTYPE ENGRAVING. This new art, patented by M. A. F. J. Claudet on the 21st November, 1843, is established on the following facts. A mixed acid, consisting of water, nitric acid, nitrate of potash, and common salt, in certain proportions, being poured upon a Daguerreotype picture, attacks the pure silver, forming a chloride of that metal, but does not affect the white parts, which are produced by the mercury of the picture. This action does not last long. Water of ammonia, containing a little chloride of silver in solution, dissolves the rest of that chloride, which is then washed away, leaving the naked metal to be again attacked, especially with the aid of heat. The metallic surface should have been perfectly purified by means of alcohol and caustic potass. For the rest of the ingenious but complex details, see *Newton's Journal*, C. S., vol. xxv., p. 112.

DAHLINE, the same as Inuline, the fecula obtained from elecampane, analogous in many respects to starch. It is not employed in the arts.

DAMASCUS BLADES, are swords or scymitars, presenting upon their surface a variegated appearance of *watering*, as white, silvery, or black veins, in fine lines, or fillets; fibrous, crossed, interlaced or parallel, &c. They are brought from the East, being fabricated chiefly at Damascus, whence their name. Their excellent quality has become proverbial; for which reason these blades are much sought after by military men, and are high priced. The oriental processes have never been satisfactorily described; but of late years methods have been devised in Europe to imitate the fabric very well.

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* See Praktische Anweisung zum Daguerrotypiren, Leipzig, &c. 1843.

Clouet and Hachette pointed out the three following processes for producing Damascus blades: 1, that of *parallel fillets;* 2, that by *torsion;* 3, the *mosaic.* The first, which is still pursued by some French cutlers, consists in scooping out with a graving tool the faces of a piece of stuff composed of thin plates of different kinds of steel These hollows are by a subsequent operation filled up, and brought to a level with the external faces, upon which they subsequently form tress-like figures. 2. The method of torsion which is more generally employed at present, consists in forming a bundle of rods or slips of steel, which are welded together into a well-wrought bar, twisted several times round its axis. It is repeatedly forged, and twisted alternately; after which it is slit in the line of its axis, and the two halves are welded with their outsides in contact; by which means their faces will exhibit very various configurations. 3. The mosaic method consists in preparing a bar, as by the torsion plan, and cutting this bar into short pieces of nearly equal length, with which a fagot is formed and welded together; taking care to preserve the sections of each piece at the surface of the blade. In this way, all the variety of the design is displayed, corresponding to each fragment of the cut bar.

The blades of Clouet, independently of their excellent quality, their flexibility, and extreme elasticity, have this advantage over the oriental blades, that they exhibit in the very substance of the metal, designs, letters, inscriptions, and, generally speaking, all kinds of figures which had been delineated beforehand.

Notwithstanding these successful results of Clouet, it was pretty clear that the watered designs of the true Damascus cimeter were essentially different. M. Bréant has at last completely solved this problem. He has demonstrated that the substance of the oriental blades is a cast-steel more highly charged with carbon than our European steels, and in which, by means of a cooling suitably conducted, a crystallization takes place of two distinct combinations of carbon and iron. This separation is the essential condition; for if the melted steel be suddenly cooled in a small crucible or ingot, there is no damascene appearance.

If an excess of carbon be mixed with iron, the whole of the metal will be converted into steel; and the residuary carbon will combine in a new proportion with a portion of the steel so formed. There will be two distinct compounds; namely, pure steel, and carbureted steel or cast-iron. These at first being imperfectly mixed will tend to separate, if while still fluid they be left in a state of repose; and form a crystallization in which the particles of the two compounds will place themselves in the crucible in an order determined by their affinity and density conjoined. If a blade forged out of steel so prepared be immersed in acidulous water, it will display a very distinct Damascus appearance; the portions of pure steel becoming black, and those of carbureted steel remaining white, because the acids with difficulty disengage its carbon. The slower such a compound is cooled, the larger the Damascus veins will be. Travernier relates that the steel crucible ingots, like those of wootz, for making the true oriental Damascus, come from Golconda, that they are of the size of a halfpenny roll, and when cut in two, form two swords.

Steel combined with manganese forges easily, but it is brittle when cold; it displays however the Damascus appearance very strongly.

A mixture of 100 parts of soft iron, and 2 of lamp black, melts as readily as ordinary steel. Several of the best blades which M. Bréant presented to the Société d'Encouragement are the product of this combination. This is an easy way of making cast-steel without previous cementation of the iron. 100 parts of filings of very gray cast-iron, and 100 parts of like filings previously oxydized, produced, by their fusion together, a beautiful damascene steel, fit for forging into white arms, sabres, swords, &c. This compound is remarkable for its elasticity, an essenial quality, not possessed by the old Indian steel. The greater the proportion of the oxydized cast-iron, the tougher is the steel. Care should be taken to stir the materials during their fusion, before it is allowed to cool; otherwise they will not afford a homogeneous damasc. If the steel contains much carbon it is difficult to forge, and cannot be drawn out except within a narrow range of temperature. When heated to a red-white it crumbles under the hammer; at a cherry-red it becomes hard and brittle; and as it progressively cools it becomes still more unmalleable. It resembles completely Indian steel, which European blacksmiths cannot forge, because they are ignorant of the suitable temperature for working it. M. Bréant, by studying this point, succeeded in forging fine blades.

Experience has proved that the orbicular veins, called by the workmen *knots* or *thorns* (*ronces*), which are seen upon the finest Eastern cimeters, are the result of the manner of forging them, as well as the method of twisting the Damascus bars. If these be drawn in length, the veins will be longitudinal; if they be spread equally in all directions, the stuff will have a crystalline aspect; if they be made wavy in the two directions, undulated veins will be produced like those in the oriental Damascus.

DAMASK is a variegated textile fabric, richly ornamented with figures of flowers,

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fruits, landscapes, animals, &c., woven in the loom, and is by far the most rich, elegant, and expensive species of ornamental weaving, tapestry alone excepted. The name is said to be derived from Damascus, where it was anciently made.

Damask belongs to that species of texture which is distinguished by practical men by the name of tweeling, of which it is the richest pattern. The tweel of damask is usually half that of full *satin*, and consequently consists of eight leaves moved either in regular succession or by regular intervals, eight leaves being the smallest number which will admit of alternate tweeling at equal intervals.

In the article Carpet, two representations have been given of the damask draw-loom.

The generic difference of tweeling, when compared with common cloth, consists in the intersections, although uniform and equidistant, being at determinate intervals, and not between the alternate threads. Hence we have specimens of tweeled cloth, where the intersections take place at the third, fourth, fifth, sixth, seventh, eighth, or sixteenth interval only. The threads thus deflecting only from a straight line at intervals, preserve more of their original direction, and a much greater quantity of materials can be combined in an equal space, than in the alternate intersection, where the tortuous deflection, at every interval, keeps them more asunder. On this principle tweeled cloths of three and four leaves are woven for facility of combination alone. The coarser species of ornamented cloths, known by the names of dornock and diaper, usually intersect at the fifth, or half satin interval. The sixth and seventh are rarely used, and the intersection at the eighth is distinguished by the name of satin in common, and of damask in ornamental tweeling. It will further be very obvious, that where the warp and woof cross only at every eighth interval, the two sides of the cloth will present a diversity of appearance; for on one side the longitudinal or warp threads will run parallel from one end of a web to the other, and, on the other, the threads of woof will run also parallel, but in a transverse direction across the cloth, or at right angles to the former. The points of intersection being only at every eighth interval, appear only like points; and in regular tweeling these form the appearance of diagonal lines, inclined at an angle of 45° (or nearly so) to each of the former.

The appearance, therefore, of a piece of common tweeled cloth is very similar to that of two thin boards glued together, with the grain of the upper piece at right angles to that of the under one. That of an ornamental piece of damask may, in the same manner, be very properly assimilated to a piece of veneering, where all the wood is of the same substance and color, and where the figures assume a diversity of appearance from the ground, merely by the grain of the one being disposed perpendicularly to that of the other. See Textile Fabric.

From this statement of the principle, it results that the most unlimited variety of figures will be produced, by constructing a loom by which every individual thread of warp may be placed either above or below the woof at every intersection; and to effect this, in boundless variety, is the object of the Jacquard mounting; which see.

The chief seat of this manufacture is probably the town and neighborhood of Dunfermline, in Fifeshire, and Lisburn and Ardoyne, near Belfast, where it is considered as the staple, having proved a very profitable branch of traffic to the manufacturer, and given employment to many industrious people.

The material used there is chiefly linen; but many have been recently woven of cotton, since the introduction of that article into the manufacture of cloth has become so prevalent. The cotton damasks are considerably cheaper than those of linen; but are not considered either so elegant or durable. The cotton, also, unless frequently bleached, does not preserve the purity of the white color nearly so well as the linen.

DAMASKEENING; the art of ornamenting iron, steel, &c., by making incisions upon its surface, and filling them up with gold or silver wire; chiefly used in enriching sword blades, guards, and gripes, locks of pistols, &c.

Its name shows the place of its origin, or, at least, the place where it has been practised in the greatest perfection; viz., the city of Damascus, in Syria; though M. Felibien attributes the perfection of the art to his countryman, Cursinet, who wrought under the reign of Henry IV.

Damaskeening is partly mosaic work, partly engraving, and partly carving. As mosaic work it consists of pieces inlaid; as engraving, the metal is indented, or cut in intaglio; and as carving, gold and silver are wrought into it in *relievo*.

There are two ways of damaskeening; in the first, which is the most beautiful, the artists cut into the metal with a graver, and other tools proper for engraving upon steel, and afterwards fill up the incisions, or notches, with a pretty thick silver or gold wire. In the other, which is only superficial, they content themselves to make hatches, or strokes across the iron, &c., with a cutting knife, such as is used in making small files. As to the first, it is necessary for the gravings or incisions to be made in the dove tail form; that the gold or silver wire, which is thrust forcibly into them, may adhere the more strongly. As to the second, which is the more usual, the method is this:—Having heated the steel till it changes to a violet, or blue color, they hatch it over and across with the knife; then draw the ensign or ornament intended, upon this hatching, with a fine brass point or bodkin. This done, they take fine gold wire, and conducting or chasing it according to the figures already designed, they sink it carefully into the hatches of the metal with a copper tool.

DAMASSIN is a kind of damask, with gold and silver flowers, woven in the warp and woof; or occasionally with silk organzine.

DAMPS, in mining, are noxious exhalations, or rather gases, so called from the German *dampf*, vapor. There are two principal kinds of mine gases, the *fire-damp*, or carburetted hydrogen, and the *choke-damp*, or carbonic acid gas. See MINES.

DAPHNINE; the bitter principle of the *Daphne Alpina.*

DATOLITE. A mineral composed of silica, lime, and boracic acid.

DECANTATION (Eng. and Fr.; *Abgiessen*, Germ.) is the act of pouring off the clear supernatant fluid from any sediment or deposite. It is much employed in the chemical arts; and is most conveniently effected by a syphon.

DECOCTION (Eng. and Fr.; *Abkochung*, Germ.) means either the act of boiling a liquid along with some organic substance, or the liquid compound resulting from that act.

DECOMPOSITION (Eng. and Fr.; *Zersetzung*, Germ.) is the separation of the constituent principles of any compound body. The following table, the result of important researches recently made by M. Persoz, Professor of Chemistry at Strasburgh, shows the order in which decompositions take place among the successive substances.

Nitric Acid.	Muriatic Acid.
Oxyde of Magnesium	Oxyde of Magnesium
— Silver	— Cobalt
— Cobalt	— Nickel
— Nickel	Protox. of Mercury
Protox. of Cerium	— Cerium
Oxyde of Zinc	Oxyde of Zinc
Protox. of Manganese	Protox. of Manganese
Oxyde of Lead	— Iron
— Cadmium	— Uranium
— Copper	— Copper
— Glucinum	— Tin
— Alumium	Oxyde of Glucinum
— Uranium	— Alumium
— Chromium	— Uranium
Protox. of Mercury	— Chromium
Oxyde of Mercury	— Iron
— Iron	— Tin
— Bismuth	— Bismuth
	— Antimony

By means of the cupric oxyde we may separate, 1, the ferric oxyde from the manganous oxyde; 2, the cobaltic, nickelic, zincic and cerous oxydes from the uranic, ferric, chromic, and aluminic oxydes; 3, the ferrous oxyde from the chromic oxyde, when dissolved in the muriatic acid.

In boiling a muriatic solution of the cobaltic, nickelic, and manganous oxydes, with the mercuric oxyde, the first two oxydes alone are precipitated. Alumina separates the cadmic oxyde from the bismuthic oxyde, the stannous oxyde from the stannic oxyde, and the stannous oxyde from the antimonic acid. The cupric oxyde separates also by precipitation, the aluminic, uranic, chromic, titanic, and vanadic oxydes from all the oxydes which are precipitable in the state of sulphuret, by hydrosulphuret of ammonia.

As an example of this mode of analysis—

Dissolve pech-blende in aqua regia, precipitate its copper by sulphureted hydrogen, boil the liquid along with nitric acid, in order to transform all the uranium into uranic acid. Next boil it along with cupric oxyde, which precipitates only the uranic and ferric oxydes. Redissolve the precipitate in nitric acid, and boil the solution with mercuric oxyde, which does not precipitate the ferric oxyde. Finally, separate the copper and the mercury from the uranium, by means of sulphureted hydrogen. In this process we may substitute plumbic oxyde for the cupric oxyde, and succeed equally well.

Knowledge, like the above, of the elective affinities and habitudes of chemical bodies, simple and compound, imparts to its possessor an irresistible power over the unions and disunions of the elements, which he can exercise with certainty in effecting innumerable transformations in the arts.

DECREPITATION (Eng. and Fr.; *Verknistern*, Germ.) is the crackling noise attended with the flying asunder of their parts, made by several salts and minerals, when heated. It is caused by the unequal sudden expansion of their substance by the heat. Sulphate of baryta, chloride of sodium, calcareous spar, nitrate of baryta, and many more bodies which contain no water, decrepitate most violently, separating at the natural joints of their crystalline structure. Some chemists have preposterously enough ascribed the phenomenon to the expansion of the combined water into steam. What a specimen of inductive philosophy!

DEFECATION (Eng. and Fr.; *Klaren*, Germ.), the freeing from dregs or impurities.

DEFLAGRATION (Eng. and Fr.; *Verpuffung*, Germ.), the sudden blazing up of a combustible; as of a charcoal or sulphur when thrown into melted nitre.

DELPHINIA. The vegeto-alkaline principle of the *Delphinium staphysagria*, or stavesacre. It is poisonous.

DELIQUESCENT (*Zerfliessen*, Germ.) is said of a solid which attracts so much moisture from the air as to become spontaneously soft or liquid; such as potash and muriate of lime.

DEPHLEGMATION is the process by which liquids are deprived of their watery particles. It is applied chiefly to spirituous liquors, and is now nearly obsolete, as involving the alchemistical notion of a peculiar principle called phlegm.

DEPHLOGISTICATED; deprived of phlogiston, — formerly supposed to be the common combustible principle. It is nearly synonymous with oxygenated. The idea originally attached to the word having proceeded from false logic, the word itself should never be used either in science or manufactures.

DEPILATORY (*Depilatoire*, Fr.; *Enthaarensmittel*, Germ.) is the name of any substance capable of removing hairs from the human skin without injuring its texture. They act either mechanically or chemically. The first are commonly glutinous plasters formed of pitch and rosin, which stick so closely to the part of the skin where they are applied, that when removed, they tear away the hairs with them. This method is more painful, but less dangerous than the other, which consists in the solvent action of a menstruum, so energetic as to penetrate the pores of the skin, and destroy the bulbous roots of the hairs. This is composed either of caustic alkalis, sulphuret of baryta, or arsenical preparations. Certain vegetable juices have also been recommended for the same purpose; as spurge and acacia. The bruised eggs of ants have likewise been prescribed. But the *oriental rusma* yields to nothing in depilatory power. Gadet de Gassincourt has published in the *Dictionnaire des Sciences Medicales*, the following recipe for preparing it.

Mix two ounces of quicklime with half an ounce of orpiment or realgar, (sulphuret of arsenic;) boil that mixture in one pound of strong alkaline ley, then try its strength by dipping a feather into it, and when the flue falls off, the *rusma* is quite strong enough. It is applied to the human skin by a momentary friction, followed by washing with warm water. Such a caustic liquid should be used with the greatest circumspection, beginning with it somewhat diluted. A soap is sometimes made with lard and the above ingredients; or soft soap is combined with them; in either case to form a depilatory pommade. Occasionally one ounce of orpiment is taken to eight ounces of quicklime, or two to twelve, or three to fifteen; the last mixture being of course the most active. Its causticity may be tempered by the addition of one eighth of starch or rye flour, so as to form a soft paste, which being laid upon the hairy spot for a few minutes, usually carries away the hairs with it.

The *rusma* should never be applied but to a small surface at a time, for independently of the risk of corroding the skin, dangerous consequences might ensue from absorption of the arsenic.

DEPOSITION OF METALS. Felted fabrics have been coated with metals of various kinds, by means of electricity, in the following way:—A plate of copper, for example, as a dye or matrix, is coated on one side with a resinous, non-conducting varnish, and on the other with graphite or plumbago, and the cloth is strained over it, and cemented to it. The matrix being immersed in a solution of sulphate of copper, and connected with a zinc pole of a galvanic battery; while another plate of copper is immersed in the solution and connected with the copper pole of the battery, the deposition of the metal upon the matrix commences. When the surface of the matrix is covered with a thin film of copper, the depositing metal begins to penetrate the interstices of the cloth, and if the operation is continued sufficiently long, will appear in small globules at the other side. As soon as the required thickness of metal has been deposited, the matrix is removed from the solution, and the cloth separated therefrom. The surface of the metallic coating will be either plain or ornamented, according as the surface of the matrix is prepared, whether with a raised or sunk pattern. And the metallic deposit may be afterward gilt or otherwise ornamented. Other details are given in the specification of M. Julius Schatlaender.—*Newton's Journal*, C. S., xxv., 96.

DESICCATING APPARATUS. The useful problem of depriving timber of its moisture has received a complete solution by Messrs. Davison & Symington, who in November, 1843, patented a method of transmitting currents of air highly heated (by an arrangement similar to those employed in the hot blast of iron-smelting), through casks made of green wood, or through chambers in which the deals or planks are piled up. The same means have since been found effective for cleansing old tainted beer tuns, or wine hogsheads, of their fermentative qualities; and hence they are now very generally had recourse to in breweries. A fan or other blowing machine is used for propelling the heated air. Mechanical friction with chains or otherwise is used in conjunction with the ventilating process.

Desiccating System. "When we first noticed this system we instanced its application to the seasoning of beer casks, as the most striking exemplification of its efficacy which then offered itself to our observation; but though we have been fully borne out in our views of the importance of that application, by the subsequent adoption of Messrs. Davison & Symington's plans in some of the largest breweries in the kingdom, this turns out to be, after all, but one of the least of the triumphs which the system has achieved. From the seasoning of casks the patentees have gone on, step by step, till they now undertake seasoning of wood and wooden articles of every description; and give fair promise of benefiting largely, not only every art and manufacture of which wood is an element, but the public at large. We have been obligingly permitted by them to inspect and make extracts from their 'Dry Seasoning Book,' and some of these extracts afford the best possible proofs of the advantages derivable from this desiccating system. They are records of work actually done—not by way of experiment merely, but in the ordinary course of an established and fast increasing trade. Each extract shows, first, the weight of the wood when sent in to be seasoned; next, the daily diminution in weight produced by the desiccating process; and lastly, the total quantity of moisture expelled—moisture which if allowed to remain in the wood could tend only to produce rot and decay. The extracts give also, in the case of planks, the degree of shrinkage in width produced. Some of the results are exceedingly startling. Mahogany is reduced in weight by desiccation 24·4 per cent., and pine planks 34·5. The woods least affected are fir and white deal, which lose 12·50 per cent. The degree of shrinkage produced is still more remarkable; amounting, in both the cases noticed, to no less than three fourths. It will be observed, moreover, that all these effects are produced in the course of a few days, some ten or twelve at most, while by the ordinary mode of drying they could hardly be accomplished in as many months." —*Mr. Robertson, in his Mechanics' Magazine.*

We need scarcely add that the less moisture there is left in wood, the greater its strength—the more complete its fitness for every purpose to which it can be applied.

DETONATION. See Fulminating, for the mode of preparing detonating powder for the percussion caps of fire-arms.

DEUTOXIDE literally means the second oxide, but is usually employed to denote a compound containing two atoms or two prime equivalents of oxygen to one or more of a metal. Thus we say deutoxide of copper, and deutoxide of mercury. Berzelius has abbreviated this expression by adopting the principles of the French nomenclature of 1787; according to which the higher stage of oxidizement is characterized by the termination *ic*, and the lower by *ous*, and he writes accordingly cupric and mercuric, to designate the deutoxides of these two metals; cuprous and mercurous to designate their protoxides. I have adopted this nomenclature in the article Decomposition, and in some other parts of this Dictionary, as being short and sufficiently precise.

DEXTRINE is a matter of a gummy appearance into which the interior substance of the molecules of starch are converted, through the influence of diastase or acids. It derives its names from the circumstance that it turns, more than any other body, the plane of polarization to the right hand. It is white, insipid, without smell, transparent, in thin plates, friable, with a glassy fracture when well dried. It is not altered by the heat of boiling water, but at 280° F. it becomes brown, and acquires the flavor of toasted bread. It is not colored by iodine, like starch, it does not form mucic acid with the nitric, as common gum does, and it is transformed into grape sugar, when heated along with dilute sulphuric acid or diastase.

Dextrine is much employed by the French pastrycooks and confectioners: it is a good substitute for gum arabic in medicine. For the conversion of potato or other starch into dextrine, by the action of diastase, see Brewing.

This substance has exactly the same chemical composition as starch, consisting of 24 atoms of carbon, 20 of hydrogen, and 10 of oxygen (Dumas); but it is distinguished from starch by its solubility in cold water, like gum, and not being affected by iodine. British gum, as it is called, or roasted starch, is merely dextrine somewhat discolored a substance apparently used for the paste on the Queen's head post office letter stamps. A process discovered by M. Payen, and patented in France by M. Henzé, for making dextrine, consists in moistening one ton of dry starch with water containing 4½ lbs. of strong nitric acid. The starch thus uniformly wetted, is made up into small bricks or loaves, and dried in a stove. It is then rubbed down into a coarse powder, and exposed in a stove-room to a stream of air heated to about 160° F. Being now triturated, sifted, and heated in a stove to about 228° F., it forms a perfect dextrine of a fair color, because the acid acts as a substitute for the higher heat, used in making the British gum. Such an article makes a fine dressing for muslin and silk goods, and is much employed in French surgery, for making a stiff paste support to the bandages of fractured limbs.

DIAMOND. Since this body is merely a condensed form of carbon, it cannot in a chemical classification be ranked among stones; but as it forms in commerce the most precious of the gems, it claims our first attention in a practical treatise on the arts. Diamonds are distinguishable by a great many peculiar properties, very remarkable and easily recognised, both in their rough state, and when cut and polished. Their most absolute and constant character is a degree of hardness superior to that of every mineral, whence diamonds scratch all other bodies, and are scratched by none. Their peculiar adamantine lustre, not easy to define, but readily distinguishable by the eye from that of every other gem, is their most obvious feature. Their specific gravity is 3·55. Whether rough or polished, diamonds acquire by friction positive electricity, but do not retain it for more than half an hour. The natural form of diamonds is derivable from an octahedron, and they never present crystals having one axis longer than the other. Their structure is very perceptibly lamellar, and therefore, notwithstanding their great hardness, they are brittle and give way in the line of their cleavage, affording a direct means of arriving at their primitive form, the regular octahedron.

The diamond possesses either single or double refraction, according to its different crystalline forms; its refractive power on light is far greater than it ought to be in the ratio of its density; the index of refraction being 2·44, whence Newton long ago supposed it to consist of inflammable matter. Its various forms in nature present a circumstance peculiar to this body; its faces are rarely terminated by planes, like most other native crystals, but they are often rounded off, and the edges between them are curved. When these secondary faces are attentively examined with a lens, we remark that they are marked with striæ, sometimes very fine and almost imperceptible, but at others well defined; and that these striæ are parallel to the edges of the octahedron, and consequently to those of the plates that are applied on the primitive faces of this figure.

Diamonds are usually colorless and transparent; when colored, their ordinary tint verges upon yellow, or smoke-yellow, approaching sometimes to blackish-brown. Green diamonds are next to yellow the most common; the blue possess rarely a lively hue, but they are much esteemed in Scotland. The rose or pink diamonds are the most valued of the colored kind, and exceed sometimes in price the most limpid; though generally speaking the latter are the most highly prized.

The geological locality of the diamond seems to be in diluvial gravel, and among conglomerate rocks; consisting principally of fragments of quartz, or rolled pebbles of quartz mixed with ferruginous sand, which compose sometimes hard aggregated masses. This kind of formation is called *cascalho* in Brazil. Its accompanying minerals are few in number, being merely black oxyde of iron, micaceous iron ore, pisiform iron ore, fragments of slaty jasper, several varieties of quartz, principally amethyst. In Mr. Heuland's splendid collection there was a Brazilian diamond imbedded in brown iron ore; another in the same, belonging to M. Schuch, librarian to the Crown Princess of Portugal; and in the cabinet of M. Eschwege there is a mass of brown iron ore, containing a diamond in the drusy cavity of a green mineral, conjectured to be arseniate of iron. From these facts it may be inferred with much probability that the matrix or original repository of the diamond of Brazil is brown iron ore, which occurs in beds of slaty quartzose micaceous iron ore, or in beds composed of iron-glance and magnetic iron ore, both of which are apparently subordinate in that country to primitive clay slate.

The loose earth containing diamonds lies always a little way beneath the surface of the soil, towards the lower outlet of broad valleys, rather than upon the ridges of the adjoining hills.

Only two *places* on the earth can be adduced with certainty as diamond mines, or rather districts; a portion of the Indian peninsula, and of Brazil.

India has been celebrated from the most remote antiquity as the country of diamonds. Its principal mines are in the kingdoms of Golconda and Visapour, extending from

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Cape Comorin to Bengal, at the foot of a chain of mountains called the *Orixa*, which appear to belong to the trap-rock formation. In all the Indian diamond soils, these gems are so dispersed, that they are rarely found directly, even in searching the richest spots, because they are enveloped in an earthy crust, which must be removed before they can be seen. The stony matter is therefore broken into pieces, and is then, as well as the looser earth, washed in basins scooped out on purpose. The gravel thus washed is collected, spread out on a smooth piece of ground, and left to dry. The diamonds are now recognised by their sparkling in the sun, and are picked out from the stones.

The diamond mines of Brazil were discovered in 1728, in the district of Serro-do-Frio. The ground in which they are imbedded has the most perfect resemblance to that of the East Indies, where the diamonds occur. It is a solid or friable conglomerate, consisting chiefly of a ferruginous sand, which encloses fragments of various magnitude of yellow and bluish quartz, of schistose jasper, and grains of gold disseminated with oligist iron ore; all mineral matters different from those that constitute the neighboring mountains; this conglomerate, or species of pudding-stone, almost always superficial, occurs sometimes at a considerable height on the mountainous table-land. The most celebrated diamond mine is that of Mandarga, on the Jigitonhonha, in the district of Serro-do-Frio to the north of Rio Janeiro. The river Jigitonhonha, three times broader than the Seine at Paris, and from 3 to 9 feet deep, is made nearly dry, by drawing the waters off with sluices at a certain season; and the *cascalho* or diamond-gravel is removed from the channel by various mechanical means, to be washed elsewhere at leisure. This cascalho, the same as the matrix of the gold mines, is collected in the dry season, to be searched into during the rainy; for which purpose it is formed into little mounds of 15 or 16 tons weight each. The washing is carried on beneath an oblong shed, by means of a stream of water admitted in determinate quantities into boxes containing the cascalho. A negro washer is attached to each box; inspectors are placed at regular distances on elevated stools, and whenever a negro has found a diamond, he rises up and exhibits it. If it weighs 17½ carats, he receives his liberty. Many precautions are taken to prevent the negroes from secreting the diamonds. Each squad of workmen consists of 200 negroes, with a surgeon and an almoner or priest.

The flat lands on either side of the river are equally rich in diamonds over their whole surface, so that it becomes very easy to estimate what a piece of ground not yet washed may produce.

It is said that the diamonds surrounded with a greenish crust are of the *first* water, or are the most limpid when cut. The diamonds received in the different mines of the district are deposited once a month in the treasury of Tejuco; and the amount of what was thus delivered from 1801 to 1806, may be estimated at about 18 or 19 thousand carats *per annum*.

On the banks of the torrent called Rio Pardo, there is another mine of diamonds. The ground presents a great many friable rocks of pudding-stone, distributed in irregular strata. It is chiefly in the bed of this stream that masses of cascalho occur, peculiarly rich in diamonds. They are much esteemed, particularly those of a greenish-blue color. The ores that accompany the diamond at Rio Pardo differ somewhat from those of the washing grounds of Mandanga, for they contain no pisiform iron ore; but a great many pebbles of slaty jasper. This table land seems to be very high, probably not less than 5500 feet above the level of the sea.

Tocaya, a principal village of Minas Novas, is 34 leagues to the northeast of Tejuco, in an acute angle of the confluence of the Jigitonhonha and the Rio Grande. In the bed of the streamlets which fall westward into the Jigitonhonha, those rolled white topazes are found which are known under the name of *minas novas* with *blue topazes*, and aquamarine beryls. In the same country are found the beautiful cymophanes or crysoberyls so much prized in Brazil. And it is from the cantons of Indaia and Abaite that the largest diamonds of Brazil come; yet they have not so pure a water as those of the district of Serro-do-Frio, but incline a little to the lemon yellow.

Diamonds are said to come also from the interior of the island of Borneo, on the banks of the river Succadan, and from the peninsula of Malacca.

It is known that many minerals become phosphorescent by heat, or exposure to the sun's light. Diamonds possess this property, but all not in equal degree, and certain precautions must be observed to make it manifest. Diamonds need to be exposed to the sunbeam for a certain time, in order to become self-luminous; or to the blue rays of the prismatic spectrum, which augment still more the faculty of shining in the dark. Diamonds susceptible of phosphorescence exhibit it either after a heat not raised to redness, or the electric discharge. They possess not only a great refractive power in the mean ray of light, but a high dispersive agency, which enables them to throw out the most varied and vivid colors in multiplied directions.

Louis de Berquem discovered, in 1476, the art of cutting diamonds by rubbing them

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against one another, and of polishing them with their own powder. These operations may be abridged by two methods: 1. by availing ourselves of the direction of the laminæ of the diamond to split them in that direction, and thus to produce several facets. This process is called cleaving the diamond. Some, which appear to be *macle* crystals, resist this mechanical division, and are called *diamonds of nature.* 2. by sawing the diamonds by means of a very delicate wire, coated with diamond powder.

Diamonds take precedence of every gem for the purpose of dress and decoration; and hence the price attached to those of a pure water increases in so rapid a proportion, that, beyond a certain term, there is no rule of commercial valuation. The largest diamond that is known seems to be that of the Rajah of Mattan, in the East Indies. It was of the purest water, and weighs 367 carats, or at the rate of 4 grains to a carat, upward of 3 ounces troy. It is shaped like an egg, with an indented hollow near the smaller end; it was discovered at Landak about 100 years ago; and though the possession of it has cost several wars, it remained in the Mattan family for 90 years. A governor of Batavia, after ascertaining the qualities of the gem, wished to be the purchaser, and offered 150,000 dollars for it, besides two war brigs with their guns and ammunition, together with a certain number of great guns, and a quantity of powder and shot. But this diamond possessed such celebrity in India, being regard as a talisman involving the fortunes of the Rajah and his family, that he refused to part with it at any price.

The Mogul diamond passed into the possession of the ruling family of Kabul, as has been invariably affirmed by the members of that family, and by the jewellers of Delhi and Kabul. It has been by both parties identified with the great diamond, now known under the name of the Koh-i-Noor, or *mountain of light*, which was displayed by its present proprietor, her Majesty the Queen, at the recent Great Exhibition. It is now being properly cut by skilful Dutch artists, under the charge of Messrs. Garrard, jewellers in London, in order to bring out all its lustre, and remove some superficial specks or clouds. The weight of it has been of old various stated.

The diamond possessed, in the time of the traveller Tavernier, by the emperor of Mogul, a kingdom now no more, weighed 279 carats, and was reckoned worth upwards of 400,000*l.* sterling. It was said to have lost the half of its original weight in the cutting. After these prodigious gems, the next are:—1. That of the emperor of Russia, bought by the late empress Catharine, which weighs 193 carats. It is said to be of the size of a pigeon's egg, and to have been bought for 90,000*l.*, besides an annuity to the Greek merchant of 4000*l.* It is reported that the above diamond formed one of the eyes of the famous statue of Sheringan, in the temple of Brama, and that a French grenadier, who had deserted into the Malabar service, found the means of robbing the pagoda of this precious gem; and escaped with it to Madras, where he disposed of it to a ship captain for 2,000*l.*, who resold it to a Jew for 12,000*l.* From him it was transferred for a large sum to the Greek merchant. 2. That of the emperor of Austria, which weighs 139 carats, and has a slightly yellowish hue. It has, however, been valued at 100,000*l.* 3. That of the king of France, called the Regent or Pitt diamond, remarkable for its form and its perfect limpidity. Although it weighs only 136 carats, its fine qualities have caused it to be valued at 160,000*l.*, though it cost only 100,000*l.*

The largest diamond furnished by Brazil, now in possession of the crown of Portugal, weighs, according to the highest estimates, 120 carats. It was found in the streamlet of Abaïte, in a clay-slate district.

The diamonds possessed of no extraordinary magnitude, but of a good form and a pure water, may be valued by a certain standard rule. In a brilliant, or rose-diamond of regular proportions, so much is cut away that the weight of the polished gem does not exceed one half the weight of the diamond in the rough state; whence the value of a cut diamond is esteemed equal to that of a similar rough diamond of double weight, exclusive of the cost of workmanship. The weight and value of diamonds are reckoned by carats of 4 grains each; and the comparative value of two diamonds of equal quality but different weights, is as the squares of these weights respectively. The average price of rough diamonds that are worth working is about 2*l.* for one of a single carat; but as a polished diamond of one carat must have taken one of 2 carats, its price in the rough state is double the square of 2*l.*, or 8*l.* Therefore, to estimate the value of a wrought diamond, ascertain its weight in carats, double that weight, and multiply the square of this product by 2*l.*

Hence, a wrought diamond of	1 carat	is worth	£ 8
	2	—	32
	3	—	72
	4	—	128
	5	—	200
	6	—	288

£
of 7 carats is worth 392
8 — 512
9 — 612
10 — 800
20 — 3200, beyond which weight the prices can no longer rise in this geometrical progression, from the small number of purchasers of such expensive toys. A very trifling spot or flaw of any kind lowers exceedingly the commercial value of a diamond.

Diamonds are used not only as decorative gems, but for more useful purposes, as for cutting glass by the glazier, and all kinds of hard stones by the lapidary.

On the structure of the glazier's diamond we possess some very interesting observations and reflections by Dr. Wollaston. He remarks, that the hardest substances brought to a sharp point scratch glass, indeed, but do not cut it, and that diamonds alone possessed that property; which he ascribes to the peculiarity of its crystallization in rounded faces and curvilinear edges. For glass-cutting, those rough diamonds are always selected which are sharply crystallized, hence called diamond sparks; but cut diamonds are never used. The inclination to be given to a set diamond in cutting glass is comprised within very narrow limits; and it ought, moreover, to be moved in the direction of one of its angles. The curvilinear edge adjoining the curved faces, entering as a wedge into the furrow opened up by itself, thus tends to separate the parts of the glass; and in order that the crack which causes the separation of the vitreous particles may take place, the diamond must be held almost perpendicular to the surface of the glass. The Doctor proved this theory by an experiment. If, by suitable cutting with the wheel, we make the edges of a spinel ruby, or corundum telesie (sapphire) curvilinear, and the adjacent faces curved, these stones will cut glass as well as a glazier's diamond, but being less hard than it, they will not preserve this property so long. He found that upon giving the surface of even a fragment of flint the same shape as that of the cutting diamond, it acquired the same property; but, from its relative softness, was of little duration. The depth to which the fissure caused by the glazier's diamond penetrates, does not seem to exceed the two-hundredth of an inch.

I shall here introduce Mr. Milburn's valuable observations on the choice of rough diamonds, as published in his work on *Oriental Commerce.*

The color should be perfectly crystalline, resembling a drop of clear spring water, in the middle of which you will perceive a strong light, playing with a great deal of spirit. If the coat be smooth and bright, with a little tincture of green in it, it is not the worse, and seldom proves bad, but if there is a mixture of yellow with green, then beware of it; it is a soft greasy stone, and will prove bad.

If the stone has a rough coat, so that you can hardly see through it, and the coat be white and look as if it were rough by art, and clear of flaws or veins, and no blemish cast in the body of the stone (which may be discovered by holding it against the light), the stone will prove good.

It often happens that a stone will appear of a reddish hue on the outward coat, not unlike the color of rusty iron, yet by looking through it against the light, you may observe the heart of the stone to be white (and if there be any black spots, or flaws, or veins in it, they may be discovered by a true eye, although the coat of the stone be the same), and such stones are generally good and clear.

If a diamond appears of a greenish bright coat, resembling a piece of green glass, inclining to black, it generally proves hard, and seldom bad; such stones have been known to have been of the first water, and seldom worse than the second; but if any tincture of yellow seems to be mixed with it, you may depend on its being a very bad stone.

All stones of a milky cast, whether the coat be bright or dull, if ever so little inclining to a bluish cast, are naturally soft, and in danger of being flawed in the cutting; and though they should have the good fortune to escape, yet they will prove dead and milky, and turn to no account.

All diamonds of cinnamon color are dubious; but if of a bright coat mixed with a little green, then they are certainly bad, and are accounted among the worst of colors. You will meet with a great many diamonds of a rough cinnamon-colored coat, opaque; this sort is generally very hard, and, when cut, contain a great deal of life and spirit; but the color is very uncertain; it is sometimes white, sometimes brown, and sometimes of a fine yellow. Rough diamonds are frequently *beamy*, that is, look fair to the eye, yet are so full of veins to the centre, that no art or labor can polish them. A good diamond should never contain small spots of a white or gray color of a nebulous form; it should be free from small reddish and brownish grains, that sometimes occur on their surface, or in their interior. A good diamond should split readily in the direction of the cleavage; it sometimes happens, however, that the folia are curved, as is the case in twin crystals. When this happens, the stone does not readily cut and polish, and is therefore of inferior value.

In the cut and polished gem, the thickness must always bear a certain proportion to the breadth. It must not be too thin nor thick; for, when too thin, it loses much of its fire, and appears not unlike glass.

The term *carate* is said to be derived from the name of a bean, the produce of a species of *erythina*, a native of the district of Shangallas, in Africa, a famous mart of gold-dust. The tree is called *kuara*, a word signifying sun in the language of the country; because it bears flowers and fruit of a flame color. As the dry seeds of this pod are always of nearly uniform weight, the savages have used them from time immemorial to weigh gold. The beans were transported into India, at an ancient period, and have been long employed there for weighing diamonds. The carat of the civilized world is, in fact, an imaginary weight, consisting of 4 nominal grains, a little lighter than 4 grains troy (*poids de marc*); it requires 74 carat grains and $\frac{1}{16}$ to equipoise 72 of the other.

In valuing a cut diamond, we must reckon that one half of its weight has been lost in the lapidary's hands; whence its weight in this state should be doubled before we calculate its price by the general rule for estimating diamonds. The French multiply by 48 the square of this weight, and they call the product in francs the value of the diamond. Thus, for example, a cut diamond of 10 carats would be worth $(10 \times 2)^2 \times 48 = 19{,}200$ francs, or 768*l*., allowing only 25 francs to the pound sterling.

The diamond mines of Brazil have brought to its government, from the year 1730 till 1814, 3,023,000 carats; being at the average rate annually of 36,000 carats, or a little more than 16 lbs. weight. They have not been so productive in the later years of that period; for, according to Mr. Mawe, between 1801 and 1806, only 115,675 carats were obtained, being 19,279 a year. The actual expenses incurred by the government, during this interval, was 4,419,700 francs; and, deducting the production in gold from the washings of the diamond gravel, or *cascalho*, it is found that the rough diamonds cost in exploration, per carat, 38 francs 20 c., or nearly 31*s.* British money. The contraband is supposed to amount to one third of the above legitimate trade. Brazil is almost the only country where diamonds are mined at the present day; it sends annually to Europe from 25 to 30 thousand carats, or from 10 to 16½ lbs.

DIAMONDS, *cutting of*. Although the diamond is the hardest of all known substances, yet it may be split by a steel tool, provided a blow be applied; but this requires a perfect knowledge of the structure, because it will only yield to such means in certain directions. This circumstance prevents the workman from forming facettes or planes generally, by the process of splitting; he is therefore obliged to resort to the process of abrasion, which is technically called cutting. The process of cutting is effected by fixing the diamond to be cut on the end of a stick, or handle, in a small ball of cement, that part which is to be reduced being left to project. Another diamond is also fixed in a similar manner; and the two stones being rubbed against each other with considerable force, they are mutually abraded, flat surfaces, or facettes, being thereby produced. Other facettes are formed by shifting the diamonds into fresh positions in the cement, and when a sufficient number are produced, they are fit for polishing. The stones, when cut, are fixed for this purpose, by imbedding them in soft solder, contained in a small copper cup, the part, or facette, to be polished, being left to protrude.

A flat circular plate of cast-iron is then charged with the powder produced during the abrasion of the diamonds; and by this means a tool is formed which is capable of producing the exquisite lustre so much admired on a finely-polished gem. Those diamonds that are unfit for working, on account of the imperfection of their lustre or color, are sold, for various purposes, under the technical name of Bort. Stones of this kind are frequently broken in a steel mortar, by repeated blows, until they are reduced to a fine powder, which is used to charge metal plates, of various kinds, for the use of jewellers, lapidaries, and others. Bort, in this state of preparation, is incapable of polishing any gems; but it is used to produce flat surfaces on rubies and other precious stones.

Fine drills are made of small splinters of bort, which are used for drilling small holes in rubies, and other hard stones, for the use of watch-jewellers, gold and silver wire-drawers, and others, who require very fine holes drilled in such substances. These drills are also used to pierce holes in china, where rivets are to be inserted; also for piercing holes in artificial enamel teeth, or any vitreous substances, however hard.

DIAMOND DUST. The demand for diamond dust within a few years has increased very materially, on account of the increased demand for all articles that are wrought by it, such as cameos, intaglios, &c. Recently there has been a discovery made of the peculiar power of diamond dust upon steel; it gives the finest edge to all kinds of cutlery, and threatens to displace the hone of Hungary. It is well known that in cutting a diamond (the hardest substance in nature), the dust is placed on the teeth of the saw—to which it adheres, and thus prevents the instrument from making its way through the gem. To this dust, too, is to be attributed solely the power of man to make brilliants from rough diamonds; from the dust is obtained the perfection of the geometrical symmetry, which is one of the chief beauties of the mineral, and also that adamantine polish, which nothing can injure or affect, save a substance of its own nature.

DIAMOND MICROSCOPES were first suggested by Dr. Goring, and have been well executed by Mr. Pritchard. Previous to grinding a diamond into a spherical figure, it should be ground flat and parallel upon both sides, that by looking through it, as opticians try flint glass, we may see whether it has a double or triple refractive power, as many have, which would render it useless as a lens. Among the 14 different crystalline forms of the diamond, probably the octahedron and the cube are the only ones that will give a single vision. It will, in many cases, be advisable to grind diamond lenses plano-convex, both because this figure gives a low spherical aberration, and because it saves the trouble of grinding one side of the gem. A concave tool of cast iron, paved with diamond powder, hammered into it by a hardened steel punch, was employed by Mr. Pritchard. This ingenious artist succeeded in completing a double convex of equal radii, of about $\frac{1}{25}$ of an inch focus, bearing an aperture of $\frac{1}{30}$ of an inch with distinctness upon opaque objects, and its entire diameter upon transparent ones. This lens gives vision with a trifling chromatic aberration; in other respects, like Dr. Goring's Amician reflector, but without its darkness, its light is said to be superior to that of any compound microscope whatever, acting with the same power, and the same angle of aperture. The advantage of seeing an object without *aberration* by the interposition of only a single magnifier, instead of looking at a picture of it with an eye-glass, is evident. We thus have a simple direct view, whereby we shall see more accurately and minutely the real texture of objects.

DIAPER, is the name of a kind of cloth, used chiefly for table linen. It is known among the French by the name of *toile fourré*, and is ornamented with the most extensive figures of any kind of tweeled cloth, excepting damask. The mounting of a loom for working diaper is, in principle, much the same as a draw-loom, but the figures being less extensive, the mounting is more simple, and is wrought entirely by the weaver, without the aid of any other person. As tweeled cloths, of any number of leaves, are only interwoven at those intervals when one of the leaves is raised, the woof above, and the warp below, is kept floating or flushed, until the intersection takes place. Of consequence, the floating yarn above appears across the fabric, and that below longitudinally. This property of tweeled cloths is applied to form the ornamental figures of all kinds of tweeled goods, merely by reversing the floating yarn when necessary. In the simpler patterns, this is effected by a few additional leaves of treddles; but when the range of pattern becomes too great to render this convenient, an apparatus called a *back harness* is employed, and the cloth woven with this mounting is called diaper. Diapers are generally five-leaf tweels; that is to say, every warp floats under four threads of woof, and is raised, and of course interwoven with the fifth. This is done either successively, forming diagonals at 45° upon the cloth, or by intervals of two threads, which is called the broken tweel. The latter is generally, if not universally, adopted in the manufacture of diaper. The reason of preferring the broken to the regular tweel, where ornaments are to be formed, is very obvious. The whole depending upon reversed flushing to give the appearance of oblique or diagonal lines, through either, would destroy much of the effect, and materially injure the beauty of the fabric. The broken tweel, on the contrary, restores to the tweeled cloth a great similarity of appearance to plain, or alternately interwoven fabrics, and at the same time preserves the facility of producing ornaments by reversing the flushing. The simplest kinds of reversed tweels will be found described under TEXTILE FABRICS.

DIASTASE. This curious substance, extracted by water from crushed malt, and precipitated from that infusion by alcohol, as is described under FERMENTATION, has been made the subject of new researches by M. Guerin Varry. The conclusions deducible from his interesting experiments are the following:—

1. One part of diastase, dissolved in 30 parts of cold water, put with 408 parts of potato starch out of contact of air, did not exercise the slightest action upon this substance in the course of 63 days, under a temperature varying from 68° to 79° Fahr.

2. Two parts of diastase do not in the course of an hour cause the globules of three parts of starch to burst, at a temperature approaching very nearly to that of the hot water which bursts them into a paste. It follows that diastase acts no part in the process of germination, towards eliminating the teguments of the starch, or transforming its interior portion into sugar, and a gummy matter assimilated by plants.

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3. Diastase liquefies and saccharifies the paste of starch without absorption or disengagement of gas; a reaction which takes place equally in vacuo as in the open air.

4. 100 parts of starch made into a paste with 39 times their weight of water, mixed with 6·13 parts of diastase dissolved in 40 parts of water, and kept for an hour between 140° and 149° Fahr., afforded 86·91 parts of sugar.

5. A paste containing 100 parts of starch, and 1393 parts of water, put in contact with 12·25 parts of diastase dissolved in 367 parts of cold water, having been maintained at 68° Fahr. during 24 hours, produced 77·64 parts of sugar.

6. The preceding experiment, repeated at the temperature of melting ice, afforded at the end of 2 hours, 11·82 parts of sugar.

7. The most favorable proportions and circumstances for the production of a great quantity of sugar, are a slight excess of diastase or barley malt (at least 25 per cent. of the latter), about 50 parts of water to one of starch, and a temperature between 140° and 149° Fahr. It is of the greatest consequence for the saccharification to take place as speedily as possible, so that the sugar produced may not be left in contact with much gummy matter (*dextrine*), in which case the diastase will not convert the latter into sugar. In fact, the liquefaction and saccharification should proceed simultaneously.

8. The sugar of starch prepared either with diastase, or sulphuric acid, crystallizes in cauliflowers, or in prisms with rhomboidal facets. It has the same composition as sugar of grapes.

9. Diastase even in excess does not saccharify the gummy matter dissolved in the water along with the starch-sugar, but when the gum is insulated, it is convertible almost entirely into sugar.

10. Gum arabic, cane sugar, and beer yeast, suffer no change from diastase.

11. A watery solution of diastase readily decomposes on keeping, either in contact or out of contact of air.

12. When starch-sugar, whether obtained by means of diastase or sulphuric acid, is submitted to the spirituous fermentation, the sum of the weights of the alcohol, carbonic acid, and water of crystallization of the sugar, is less than the weight of the sugar by about 3½ per cent. This difference proceeds in a great measure from the formation of some acetic acid, lactic acid, volatile oil, and probably some other unknown products in the act of fermentation.

DIDYM. A new metal, found in oxide of cerium, and so called as being associated in that ore as a *twin* brother of *lanthanum.*

DIES FOR STAMPING. (*Coins*, Fr.; *Münzstampeln*, Germ.) The first circumstance that claims particular attention in the manufacture of dies, is the selection of the best kind of steel for the purpose, and this must in some measure be left to the experience of the die-forger, who, if well skilled in his art, will be able to form a tolerably correct judgment of the fitness of the metal for the purpose, by the manner in which it works upon the anvil. It should be rather fine-grained than otherwise, and above all things perfectly even and uniform in its texture, and free from spots and patches finer or coarser than the general mass. But the very fine and uniform steel with a silky fracture, which is so much esteemed for some of the purposes of cutlery, is unfit for our present purpose, from the extreme facility with which it acquires great hardness by pressure, and its liability to cracks and flaws. The very coarse-grained or highly crystalline steel is also equally objectionable; it acquires fissures under the die-press, and seldom admits of being equally and properly hardened. The object, therefore, is to select a steel of a medium quality as to fineness of texture, not easily acted upon by dilute sulphuric acid, and exhibiting a uniform texture when its surface is washed over with a little aqua-fortis, by which its freedom from pins of iron, and other irregularities of composition, is sufficiently indicated.

The best kind of steel being thus selected, and properly forged at a high heat into the rough die, it is softened by very careful annealing, and in that state, having been smoothed externally, and brought to a table in the turning lathe, it is delivered to the engraver.

The process of annealing the die consists in heating it to a bright cherry red, and suffering it to cool gradually, which is best effected by bedding it in a crucible or iron pot of coarsely-powdered charcoal, that of animal substances being generally preferred. In this operation it is sometimes supposed that the die, or at least its superficial parts, becomes super-carbonized, or highly-converted steel, as it is sometimes called; but experience does not justify such an opinion, and I believe the composition of the die is scarcely, certainly not materially, affected by the process, for it does not remain long enough in the fire for the purpose.

The engraver usually commences his labors by working out the device with small steel tools, in intaglio; he rarely begins in relief (though this is sometimes done); and having ultimately completed his design, and satisfied himself of its general effect and

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correctness, by impressions in clay, and dabs, or casts in type metal, the die is ready for the important operation of hardening, which, from various causes, a few of which I shall enumerate, is a process of much risk and difficulty; for should any accident now occur, the labor of many months may be seriously injured, or even rendered quite useless.

The process of hardening soft steel is in itself very simple, though not very easily explained upon mechanical or chemical principles. We know by experience that it is a property of this highly valuable substance to become excessively hard, if heated and suddenly cooled; if, therefore, we heat a bar of soft malleable and ductile steel red hot, and then suddenly quench it in a large quantity of cold water, it not only becomes hard, but fragile and brittle. But as a die is a mass of steel of considerable dimensions, this hardening is an operation attended by many and peculiar difficulties, more especially as we have at the same time to attend to the careful preservation of the engraving. This is effected by covering the engraved face of the die with a protecting face, composed of fixed oil of any kind, thickened with powdered charcoal: some persons add pipe-clay, others use a pulp of garlic, but pure lamp-black and linseed oil answer the purpose perfectly. This is thinly spread upon the work of the die, which, if requisite, may be further defended by an iron ring; the die is then placed with its face downwards in a crucible, and completely surrounded by powdered charcoal. It is heated to a suitable temperature, that is, about cherry red, and in that state is taken out with proper tongs, and plunged into a body of cold water, of such magnitude as not to become materially increased in temperature; here it is rapidly moved about, until all noise ceases, and then left in the water till quite cool. In this process it should produce a bubbling and hissing noise; if it pipes and sings, we may generally apprehend a crack or fissure.

No process has been found to answer better than the above simple and common mode of hardening dies, though others have had repeated and fair trials. It has been proposed to keep up currents and eddies of cold water in the hardening cistern, by means of delivery-pipes, coming from a height; and to subject the hot die, with its face uppermost, to a sudden and copious current of water, let upon it from a large pipe, supplied from a high reservoir; but these means have not in any way proved more successful, either in saving the die or in giving it any good qualities. It will be recollected, from the form of the die, that it is necessarily only, as it were, case-hardened; the hardest strata being outside, and the softer ones within, which envelop a core, something in the manner of the successive coats of an onion; an arrangement which we sometimes have an opportunity of seeing displayed in dies which have been smashed by a violent blow.

The hardening having been effected, and the die being for the time safe, some further steps may be taken for its protection; one of these consists in a very mild kind of tempering, produced by putting it into water, gradually raised to the boiling point, till heated throughout, and then suffering it gradually to cool. This operation renders the die less apt to crack in very cold weather. A great safeguard is also obtained by thrusting the cold die into a red-hot iron ring, which just fits it in that state, and which, by contracting as it cools, keeps its parts together under considerable pressure, preventing the spreading of external cracks and fissures, and often enabling us to employ a split or die for obtaining punches, which would break to pieces without the protecting ring.

If the die has been successfully hardened, and the protecting paste has done its duty, by preserving the face from all injury and oxydizement, or burning, as it is usually called, it is now to be cleaned and polished, and in this state constitutes what is technically called a MATRIX; it may, of course, be used as a multiplier of medals, coins, or impressions, but it is not generally thus employed, for fear of accidents happening to it in the coining press, and because the artist has seldom perfected his work upon it in this state. It is, therefore, resorted to for the purpose of finishing a PUNCH, or steel impression for relief. For this purpose a proper block of steel is selected, of the same quality, and with the same precautions as before, and being carefully annealed or softened, is turned like the matrix, perfectly true and flat at the bottom, and obtusely conical at top. In this state, its conical surface is carefully compressed by powerful and proper machinery upon the matrix, which, being very hard, soon allows it to receive the commencement of an impression; but in thus receiving the impression, it becomes itself so hard by condensation of texture as to require, during the operation, to be repeatedly annealed, or softened; otherwise it would split into small superficial fissures, or would injure the matrix; much practical skill is therefore required in taking this impression, and the punch, at each annealing, must be carefully protected, so that the work may not be injured.

Thus, after repeated blows in the die-press, and frequent annealing, the impression from the matrix is at length perfected, or brought completely up, and having been retouched by the engraver, is turned, hardened, and collared, like the matrix, of which it is now a complete impression in relief, and, as we have before said, is called a punch.

This punch becomes an inexhaustible parent of dies, without further reference to the original matrix; for now by impressing upon it plugs of soft steel, and by pursuing with them an exactly similar operation to that by which the punch itself was obtained, we procure impressions from it to any amount, which of course are fac-similes of the matrix, and these dies being turned, hardened, polished, and, if necessary, tempered, are employed for the purposes of coinage.

The distinction between striking medals and common coin is very essential, and the work upon the dies is accordingly adjusted to each. Medals are usually in very high relief, and the effect is produced by a succession of blows; and as the metal in which they are struck, be it gold, silver, or copper, acquires considerable hardness at each stroke of the press, they are repeatedly annealed during the process of bringing them up. In a beautiful medal, which Mr. Wyon some time since completed for the Royal Navy College, the obverse represents a head of the King, in very bold relief; it required thirty blows of a very powerful press to complete the impression, and it was necessary to anneal each medal after every third blow, so that they went ten times into the fire for that purpose. In striking a coin or medal, the lateral spread of the metal, which otherwise would ooze out as it were from between the dies, is prevented by the application of a steel collar, accurately turned to the dimensions of the dies, and which, when left plain, gives to the edge of the piece a finished and polished appearance; it is sometimes grooved, or milled, or otherwise ornamented, and occasionally lettered, in which case it is made in three separate and moveable pieces, confined by a ring, into which they are most accurately fitted, and so adjusted that the metal may be forced into the letters by its lateral spread, at the same time that the coin receives the blow of the screw-press.

Coins are generally completed by one blow of the coining-press. These presses are worked in the Royal Mint by machinery, so contrived that they shall strike, upon an average, sixty blows in a minute; the blank piece, previously properly prepared and annealed, being placed between the dies by part of the same mechanism.

The number of pieces which may be struck by a single die of good steel, properly hardened and duly tempered, not unfrequently amounts at the Mint to between three and four hundred thousand, but the average consumption of dies is of course much greater, owing to the variable qualities of steel, and to the casualties to which the dies are liable: thus, the upper and lower die are often violently struck together, owing to an error in the layer-on, or in that part of the machinery which ought to put the blank into its place, but which now and then fails so to do. This accident very commonly arises from the boy who superintends the press neglecting to feed the hopper of the layer-on with blank pieces. If a die is too hard, it is apt to break or split, and is especially subject to fissures, which run from letter to letter upon the edge. If too soft, it swells, and the collar will not rise and fall upon it, or it sinks in the centre, and the work becomes distorted and faulty. He, therefore, who supplies the dies for an extensive coinage has many accidents and difficulties to encounter. There are eight presses at the Mint, frequently at work for ten hours each day, and the destruction of eight pair of dies per day (one pair for each press) may be considered a fair average result, though they much more frequently fall short of, than exceed this proportion. It must be remembered that each press produces 3600 pieces per hour, but, making allowance for occasional stoppages, we may reckon the daily produce of each press at 30,000 pieces; the eight presses, therefore, will furnish a diurnal average of 240,000 pieces.

DIGESTER is the name of a strong kettle or pot of small dimensions, made very strong, and mounted with a safety valve in its top. Papin, the contriver of this apparatus, used it for subjecting bones, cartilages, &c. to the solvent action of high-pressure steam, or highly heated water, whereby he proposed to facilitate their digestion in the stomach. This contrivance is the origin of the French cookery pans, called *autoclaves*, because the lid is self-keyed, or becomes steam-tight by turning it round under clamps or ears at the sides, having been previously ground with emery to fit the edge of the pot exactly. In some autoclaves the lid is merely laid on with a fillet of linen as a lute, and then secured in its place by means of a screw bearing down upon its centre from an arched bar above. The safety valve is loaded either by a weight placed vertically upon it, or by a lever of the second kind pressing near its fulcrum, and acted upon by a weight which may be made to bear upon any point of its graduated arm.

Chevreul has made a useful application of the digester to vegetable analysis. His instrument consists of a strong copper cylinder, into which enters a tight cylinder of

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silver, having its edge turned over at right angles to the axis of the cylinder, so as to form the rim of the digester. A segment of a copper sphere, also lined with silver stops the aperture of the silver cylinder, being applied closely to its rim. It has a conical valve pressed with a spiral spring, of any desired force, estimated by a steelyard. This spring is enclosed within a brass box perforated with four holes; which may be screwed into a tapped orifice in the top of the digester. A tube screwed into another hole serves to conduct away the condensable vapors at pleasure into a Woulfe's apparatus.

DIMITY is a kind of cotton cloth originally imported from India, and now manufactured in great quantities in various parts of Britain, especially in Lancashire. Dr Johnson calls it *dimmity*, and describes it as a kind of fustian. The distinction between fustian and dimity seems to be, that the former designates a common tweeled cotton cloth of a stout fabric, which receives no ornament in the loom, but is most frequently dyed after being woven. Dimity is also a stout cotton cloth, but not usually of so thick a texture; and is ornamented in the loom, either with raised stripes or fancy figures, is seldom dyed, but usually worn white, as for bed and bed-room furniture. The striped dimities are the most common, they require less labor in weaving than the others; and the mounting of the loom being more simple, and consequently less expensive, they can be sold at much lower rates. See TEXTILE FABRICS, for particular details of the plan of mounting them.

DISINFECTION OF CLOTHING, (*Messrs. Davison and Symington's patent process*).—The absorption of noxious effluvia by clothes or soft and porous articles of merchandise, has been long recognised as a fact by men who have directed special attention to this subject.

The use of the various liquid disinfectants, which have of late been proposed, is not applicable to articles of clothing; and the common practice of baking clothes in ovens is liable to lead to their destruction, owing to the impossibility of regulating the temperature to which it is necessary to expose them. The only plan which combines economy with certainty of disinfection, is that which has been patented by Messrs. Davison and Symington, and which is now extensively employed in various manufactures. This plan consists in exposing the articles of clothing in a large chamber to rapid currents of air heated to a temperature insufficient to injure them, *i. e.* varying from 200° to 250°. We have had an opportunity of witnessing this process as applied to certain branches of manufacture, and the results were of the most satisfactory kind. In the case of infected clothing, it is obvious, that while a high temperature tends to destroy the animal poisons, a rapid current of air, constantly passing through the chamber, tends to carry them off. The temperature of the current of air can be so regulated that common albumen is speedily dried into a yellow transparent solid, without coagulation, or if necessary, the heat may be increased from 400° to 500°, according to the nature of the articles which are exposed. Dr. Copland has already directed the attention of the profession to this process, and observes that, "the great advantage of this method is its easy applicability to all kinds, and to any number of objects and articles without injury to their textures or fabrics." From an inspection of one of these chambers, when the temperature of the current of air was 116°, we can state that the process of Messrs. Davison and Symington for the drying and disinfecting of the clothing of cholera and fever patients, will be far more efficacious than the common plan of washing and baking. In our opinion, an apparatus of this kind, fitted up in large hospitals, infirmaries, prisons and workhouses, as well as all quarantine stations, would be admirably adapted to prevent the diffusion of infectious diseases.

DISTILLATION (Eng. and Fr.; *Branntweinbrennerei*, Germ.) means, in the commercial language of this country, the manufacture of intoxicating spirits; under which are comprehended the four processes, of *mashing* the vegetable materials, *cooling* the worts, exciting the vinous *fermentation*, and separating by a peculiar vessel, called a *still*, the alcohol combined with more or less water. This art of evoking the fiery demon of drunkenness from his attempered state in wine and beer, was unknown to the ancient Greeks and Romans. It seems to have been invented by the barbarians of the north of Europe, as a solace to their cold and humid clime; and was first made known to the southern nations in the writings of Arnoldus de Villa Nova, and his pupil, Raymond Lully of Majorca, who declares this admirable essence of wine to be an emanation of the Divinity, an element newly revealed to man, but hid from antiquity, because the human race were then too young to need this beverage, destined to revive the energies of modern decrepitude. He further imagined that the discovery of this *aqua vitæ*, as it was called, indicated the approaching consummation of all things—the end of this world. However much he erred as to the value of this remarkable essence, he truly predicted its vast influence upon humanity, since to both civilized and savage nations it has realized greater ills than were threatened in the fabled box of Pandora.

I shall consider in this place the first three of these subjects, reserving for the article Still an account of the construction and use of that apparatus.

Whiskey, from the Irish word Usquebaugh, is the British name of the spirituous liquor manufactured by our distillers, and corresponds to the *Eau de vie* of the French and the *Branntwein* of the Germans. It is generated by that intestine change which grape juice and other glutino-saccharine liquids spontaneously undergo when exposed to the atmosphere at common temperatures; the theory of which will be expounded under the article Fermentation. The production of whiskey depends upon the simple fact, that when any vinous fluid is boiled, the alcohol, being very volatile, evaporates first, and may thereby be separated from the aqueous vegetable infusion in which it took its birth. Sugar is the only substance which can be transformed into alcohol. Whatsoever fruits, seeds, or roots afford juices or extracts capable of conversion into vinous liquor, either contain sugar ready formed, or starch susceptible of acquiring the saccharine state by proper treatment. In common language, the intoxicating liquor obtained from the sweet juices of fruits is called wine; and that from the infusions of farinaceous seeds, beer; though there is no real difference between them in chemical constitution. A similar beverage, though probably less palatable, is procurable from the juices and infusions of many roots, by the process of fermentation. Wine, cider, beer, and fermented wash of every kind, when distilled, yields an identical intoxicating spirit, which differs in these different cases merely in flavor, in consequence of the presence of a minute quantity of volatile oils of different odors.

I. The juices of sweet fruits contain a glutinous ingredient which acts as a ferment in causing their spontaneous change into a vinous condition; but the infusions of seeds, even in their germinated or malted state, require the addition of a glutinous substance called yeast, to excite the best fermentation. In the fabrication of wine or beer for drinking, the fermentative action should be arrested before all the fruity saccharum is decomposed; nor should it on any account be suffered to pass into the acetous stage; whereas for making distillery wash, that action should be promoted as long as the proportion of alcohol is increased, because the formation of a little acetic acid is not injurious to the quality of the distilled spirit, but rather improves its flavor by the addition of acetic ether, while all the undecomposed sugar is lost. Distillers operate upon the saccharine matter from corn of various kinds in two methods; in the first they draw off a pure watery extract from the grain, and subject this species of wort to fermentation; in the second they ferment and distil the infused mass of grains. The former is the practice of the distillers in the United Kingdom, and is preferable on many accounts; the latter, which is adopted in Germany, Holland, and the north of Europe, is less economical, more uncertain in the product, and affords a cruder spirit, in consequence of the fetid volatile oil evolved from the husks in the still. The substances employed by the distillers may be distributed into the following classes:—

1. Saccharine juices. At the head of these stands cane-juice, which fresh from the mill contains from 12 to 16 per cent. of raw sugar, and like the must of the grape enters into the vinous fermentation without the addition of yeast, affording the species of spirit called Rum, which is possessed of a peculiar aroma derived from an essential oil in the cane. An inferior sort of rum is fabricated from molasses, mixed with the skimmings and washings of the sugar pans. When molasses or treacle is diluted with twenty times its weight of warm water, and when the mixture has cooled to 78° F., if one twelfth of its weight of yeast be added, fermentation will speedily ensue, and an ardent spirit will be generated, which when distilled has none of the aroma of rum; proving this to reside in the immediate juice or substance of the cane, and to be dissipated at the high temperature employed in the production of molasses. Though the cane juice will spontaneously undergo the vinous fermentation, it does so more slowly and irregularly than the routine of business requires, and therefore is quickened by the addition of the lees of a preceding distillation. So sensible are the rum distillers of the advantage of such a plan, that they soak woollen cloths in the yeast of the fermenting vats, in order to preserve a ferment from one sugar season to another. In Jamaica and some other of our colonies, 50 gallons of spent wash or lees are mixed with 6 gallons of molasses, 36 gallons of sugar-pan skimmings (a substance rich in aroma), and 8 gallons of water; in which mixture there is about one twelfth part of solid saccharum. Those who attend more to the quality than the quantity of their rum, will use a smaller proportion of the spent wash, which is always empyreumatic, and imparts more or less of its odor to the spirit distilled from it. The fermentation is seldom complete in less than 9 days, and most commonly it requires from 12 to 15; the period being dependant upon the capacity of the fermenting tun, and the quality of its contents. The liquid now becomes clear, the froth having fallen to the bottom, and few bubbles of gas are extricated from it, while its specific gravity is reduced from 1·050 down to 0·992. The sooner it is subjected to distillation after this period, the better, to prevent

the loss of alcohol by the supervention of the acetous stage of fermentation, an accident very liable to happen in the sugar colonies. The crude spirit obtained from the large single still at the first operation, is rectified in a smaller still. About 114 gallons of rum, proof strength, specific gravity 0·920, are obtained from 1200 gallons of wash. Now these 1200 gallons weigh 12,600 lbs., and contain nearly one eighth of their weight of sugar$=$1575 lbs.; which should yield nearly its own weight of proof spirit, whose bulk is$=\frac{1575}{0\cdot92}=$1712 pound measures$=$171·2 gallons; whereas only 114 are obtained; proving the processes to be conducted in a manner far from economical, even with every reasonable allowance.

Mr. Edwards gives the following estimate: "The total amount of sweets from an estate in Jamaica which makes 200 hogsheads of sugar, is 16,666 gallons. The wash set at the rate of 12 per cent. sweets should return 34,720 gallons of low wines, which should give 14,412 gallons of rum, or 131 puncheons of 110 gallons each."

By my own experiments on the quantity of proof spirit obtainable from molasses by fermentation (afterwards to be detailed), one gallon of sweets should yield one gallon of spirit; and hence the above 16,666 gallons should have afforded the same bulk of rum. But here we are left somewhat in the dark, by not knowing the specific gravity of the rum spoken of by Mr. Edwards. The only light let in upon us is when he mentions rum oil-proof, that is, a spirit in which olive oil will sink; indicating a density nearly the same with our actual excise proof, for olive oil at 60° F. has the specific gravity 0·919. When a solution of sugar of the proper strength is mixed with wine lees, and fermented, it affords a spirit by distillation not of the rum, but of the brandy flavor.

The sweet juices of palm trees and cocoa nuts, as also of the maple, and ash, birch, &c., when treated like cane juice afford vinous liquors from which ardent spirits, under various names, are obtained; as *arrack*, &c.; the quantity being about 50 pounds of alcohol of 0·825 for every 100 pounds of solid saccharine extract present. Honey similarly treated affords the metheglin so much prized by our ancestors. Good whey, freed from curd by boiling, will yield 4 per cent. of spirit of wine, when fermented with the addition of a little yeast.

2. The juices of apples, pears, currants, and such fruits, afford by fermentation quantities of alcohol proportional to the sugar they contain. But the quality of the spirit is much better when it is distilled from vinous liquids of a certain age, than from recently fermented must. Cherries are employed in Germany, and other parts of the Continent, for making a high-flavored spirit called *Kirsch-wasser*, or cherry water. The fully ripe fruit is crushed by a roller press, or an edge-stone mill, along with the kernels; the pulp is fermented in a mass, the liquid part is then drawn off, and distilled. More or less prussic acid enters from the kernels into this spirit, which renders it very injurious, as a liquor, to many constitutions. I was once nearly poisoned by swallowing a wine glass of it in the valley of Chamouni. The ripened red fruit of the mountain ash constitutes a good material for vinous fermentation. The juice being mixed with some water and a little yeast, affords when well fermented, according to Hermstaedt, 12 pounds, or ½ gallons, of alcohol from 2 bushels of the ripe berries.

3. Many roots contain sugar, particularly beet, from which no less than 7 per cent. of it may be extracted by judicious means. Hermstaedt recommends to mash the steam boiled clean roots, and add to the paste two thirds of its weight of boiling water, and a thirtieth of its weight of ground malt, mixing the materials well, and then leaving them three hours in a covered vessel. The mixture must now be passed through a wire sieve, with meshes of one third of an inch square each; the residuum is washed with a little cold water, and, when the temperature has fallen to 77° F., the proper quantity of yeast must be added, and the fermentation suffered to proceed in a covered tun. In 5 or 6 days it will be complete, and will afford by distillation, from 100 pounds of beet root, about 10 or 12 pounds of proof spirits. Carrots and parsnips, when similarly treated, yield a considerable quantity of alcohol.

II. *Ardent spirits or whiskey from fecula or starchy materials.*

I have already pointed out, in the article Beer, how the starch is transformed into a saccharine condition, by malting and mashing; and how a fermentable wort may be obtained from starchy meal. By like operations may all vegetable substances, which consist chiefly of starch, become materials for a whiskey distillery. To this class belong all the farinaceous grains, potatoes, and the pods of shell fruits, as beans, vetches, horse-chestnuts, acorns, &c.

1. *Whiskey from corn.* All those species of corn which are employed in breweries answer for distilleries; as wheat, rye, barley, and oats; as well as buckwheat, and maize or Indian corn. The product of spirits which these different grains afford, depends upon the proportion of starch they contain, including the small quantity of uncrystallizable sugar present in them. Hermstaedt, who has made exact experiments upon the subject, reckons a quart (Prussian or British) of spirits, containing 30 per cent. of the absolute alcohol of Richter, for 2 pounds of starch. Hence 100 pounds of starch should yield

35 pounds of alcohol; or 4·375 gallons imperial, equal to 7·8 gallons of spirits, excise proof.

100 pounds of the following grains afford in spirits of specific gravity 0.9427, containing 45 per cent. of absolute alcohol, (= $\frac{9}{11}$ of British proof,) the following quantities:—

Wheat, 40 to 45 pounds of spirits; rye, 36 to 42; barley, 40; oats, 36; buckwheat, 40; maize, 40. The mean of the whole may be taken at 40 pounds, equal to 4¼ gallons imperial, of 0·9427 specific gravity = 3·47 gallons, at excise proof. The chief difference in these several kinds of corn consists in their different bulks under the same weight; a matter of considerable importance; for since a bushel of oats weighs little more than the half of a bushel of wheat, the former becomes for some purposes less convenient in use than the latter, though it affords a good spirit.

Barley and rye are the species of grain most commonly employed in the European distilleries for making whiskey. Barley is mostly taken either partly or altogether in the malted state; while the other corns are not malted, but merely mixed with a certain proportion of barley malt to favor the saccharine fermentation in the mashing. It is deemed preferable to use a mixture of several sorts of grain, instead of a single one; for example, wheat with barley and oats; or barley with rye and wheat; for the husks of the oats diffused through the wheat flour and rye meal keep it open or porous when mashed, and thus favor the abstraction of the wort; while the gluten of the wheat tends to convert the starch of the barley and oats into sugar. When the whole of the grain, however, is malted, a much more limpid wort is obtained than from a mixture of malt with raw grain; hence the pure malt is preferable for the ale and porter brewer, while the mixture affords a larger product, at the same cost of materials, to the distiller. When barley is the only grain employed, from one third to one sixth of malt is usually mixed with it; but when wheat and rye are also taken, the addition of from one eighth to one sixteenth of barley malt is sufficient. Oats are peculiarly proper to be mixed with wheat, to keep the meal open in the mashing.

The following are the proportions used by some experienced Scotch distillers.

250 bolls, containing 6 bushels each, being used for a mashing, consist of,

25 bolls	of oats, weighing	284 lbs. per boll, or	47⅓ lbs. per bushel;
42	malt	240	40
25	rye	320	53⅓
158	barley	320	53⅓
250			mean 48½

From each boll, weighing 291 lbs., 14 imperial gallons of proof whiskey are obtained on an average; equivalent to 11·2 gallons at 25 over proof.

The malting for the distilleries is to be conducted on the same principles as for the breweries, but the malt ought to be lightly kiln-dried, and that preferably at a steam heat, instead of a fire, which is apt to give an empyreumatic smell to the grain that passes into the spirits. For such persons, indeed, as relish the smell of burned turf, called peat-reek in Scotland, the malt should be dried by a turf fire, whereby the whiskey will acquire that peculiar odor.

But this smell, which was originally prized as a criterion of whiskey made from pure malt, moderately fermented and distilled with peculiar care, has of late years lost its value, since the artifice of impregnating bad raw grain whiskey with peat-smoke has been extensively practised.

Dr. Kolle, in his treatise on making spirits, describes a malting kiln with a copper plate heated with steam, 18 feet long, and 12 feet broad, on which a quantity of malt being spread thin, is changed every 3 or 4 hours, so that in 24 hours he turns out upwards of 28 cwt. of an excellent and well kilned article. The malt of the distiller should be as pale as possible, because with the deepening of the color an empyreumatic principle is generated.

When Indian corn is the subject of distillation, it must be malted in the same way as described in the article Beer. According to Hermstaedt, its flour may be advantageously mixed with the crushed malt in the mash tun. But its more complete dissolution may be accomplished by Siemen's mode of operating upon potatoes, presently to be described.

1. *Mashing.* Barley and raw grain are ground to meal by millstones, but malt is merely crushed between rollers. If only one tenth or one eighth of malt be used with nine tenths or seven eighths of barley, some husks of oats are added, to render the mash mixture more drainable.

When 40 bushels of barley and 20 of malt form one mashing, from 600 to 700 gallons of water, heated to 150° F., are mixed with these 60 bushels in the mash tun, and carefully incorporated by much manual labor with wooden oars, or in great concerns by the mechanical apparatus used in the breweries. This agitation must be continued for 2 or 3 hours, with the admission from time to time of about 400 additional gallons of water, at a temperature of 190°, to counteract the cooling of the materials. But since the discovery of *diastase*, as the best heat for saccharifying starch is shown to be not higher than 160° F., it would be far better to mash in a tun, partially, at least, steam incased, whereby we could preserve the temperature at the appropriate degree for generating the greatest quantity of sugar.

If the wort be examined every half-hour of the mashing period, it will be found to become progressively sweeter to the taste, thinner in appearance, but denser in reality.

The wort must be drawn off from the grains whenever it has attained its maximum density, which seldom exceeds 150 lbs. per barrel; that is, $\frac{360 + 150}{360} = 1{\cdot}42$, or 42 per cent. As the corn of the distiller of raw grain has not the same porosity as the brewer's, the wort cannot be drawn off from the bottom of the tun, but through a series of holes at the level of the liquor, bored in a pipe stuck in at the corner of the vessel. About one third only of the water of infusion can thus be drawn off from the pasty mass. More water is therefore poured on at the temperature of 190°, well mixed by agitation for half an hour, then quietly infused for an hour and a half, and finally drawn off as before. Fully 400 gallons of water are used upon this occasion, and nearly as much liquor may be drawn off. Lastly, to extract from the grains everything soluble, about 700 gallons of boiling hot water are turned in upon them, thoroughly incorporated, then left quietly to infuse, and drawn off as above. This weak wort is commonly reserved for the first liquor of the next mashing operation upon a fresh quantity of meal and malt.

The English distiller is bound by law to make his mixed worts to be let down into the fermenting tun of a specific gravity not less than 1·050, nor more than 1·090; the Scotch and Irish distillers not less than 1·030, nor more than 1·080; which numbers are called, gravity 50, 90, 30, and 80, respectively.

With the proportion of malt, raw grain, and water, above prescribed, the infusion first drawn off may have a strength = 20 per cent. = spec. grav. 1·082, or 73 lbs. per barrel; the second of 50 lbs. per barrel, or 14 per cent.; and the two together would have a strength of 61·2 lbs. per barrel = 17 per cent., or spec. grav. 1·070. From experiments carefully made upon a considerable scale, it appears that no more than four fifths of the soluble saccharo-starchy matter of the worts is decomposed in the best regulated fermentations of the distiller from raw grain. For every 2 lbs. so decomposed, 1 lb. of alcohol, spec. grav. 0·825, is generated; and as every gallon of spirits of the spec. grav. 0·909 contains 4·6 lbs. of such alcohol, it will take twice 4·6 or 9·2 lbs. of saccharine matter to produce the said gallon. To these 9·2 lbs., truly transmuted in the process, we must add one fifth, or 1·84 lbs., which will raise to 11·04 the amount of solid matter employed in producing a gallon of the above spirits.

Some distillers mash a fourth time; and always use the feeble wort so obtained in mashing fresh grain.

2. As the imperfect saccharine infusion obtained from raw grain is much more acescent than the rich sugary solution got from malt in the breweries, the distiller must use every precaution to cool his worts as quickly as possible, and to keep them clear from any acetous taint. The different schemes of cooling worts are considered under Beer and Refrigeration. As the worts cool, a quantity of starchy matter is precipitated, but it is all carefully swept along into the fermenting tun, and undoubtedly contributes to increase the production of alcohol. During the winter and temperate months, when the distilleries are most actively at work, the temperature at which the worts are set is usually about 70° F. When much farinaceous deposite is present, the heat may be only 65°, because, in this case, a slow fermentation seems to favor the conversion of that starch into sugar. In some German distilleries a little chalk is mixed with the worts, to check acidity.

3. *The fermentation.*

The yeast added to the worts as a ferment, ought to be the best top barm of the London porter breweries. About 1 gallon of it is requisite for every 2 bushels of meal and malt worked up in the mashing process; and of this quantity only a certain proportion is introduced at the beginning; the remainder being added by degrees, on the second and third days.

Should the fermentation flag, a little more may be added on the fourth or fifth day and the contents of the tun may be roused by an agitator. About 8 or 9 gallons may be introduced four days in succession to the quantity of worts extracted from 60 bushels of the farinaceous materials; or the third day's dose may be intermitted, and joined to the fourth on the subsequent day.

Great diversity and no little caprice prevail among distillers in respect of the periods of administering the yeast; but they should be governed very much by the appearance of the fermentation. This process continues from nine to twelve or even fourteen days, according to circumstances; the tuns being left quite open during the first five days, but being covered moderately close afterwards to favour the full impregnation of the liquor with carbonic acid, as a fermenting agent. In consequence of the great attenuation of the wort by the generation of so much alcohol, no good body of yeast continues to float on the surface, and what is formed is beat down into the liquor on purpose to promote the fermentation. The temperature of the wash gradually increases till towards the end of the fourth day, when it attains its maximum height of about 25° above the pitch of 55° or 60° at which it may have been set. The time of the greatest elevation of temperature, as well as its amount, depends conjointly upon the quality of the yeast, the nature of the saccharo-starchy matter, and the state of the weather. It is highly probable that the electrical condition of the atmosphere exercises a considerable influence upon fermentation. We know the power of a thunder-storm to sour vinous fluids. An experimental inquiry into the relation between electricity and fermentation, could not fail to prove both curious and profitable.

The dimunition of the density of the wort is carefully watched by the distiller, as the true criterion of the success of his process. This *attenuation*, as he calls it, is owing partly to the decomposition of the sugar, which communicated its gravity to the solution, and partly to the introduction of the lighter alcoholic particles. Were all the saccharo-starchy matter resolved into gaseous compounds, the wort would become water; but since a part of it remains undecomposed, and a portion of alcohol is produced at the expense of the decomposed part, the degree of attenuation becomes a somewhat complicated problem in a theoretical point of view; the density due to the residuary sugar being masked and counteracted by the spirit evolved. Could the alcohol be drawn off as it is formed, the attenuation would probably become greater, because the alcohol checks the fermentative action, and eventually stops it, before all the saccharum is decomposed. After the wash has taken its highest degree of temperature, not much more spirit is found to be generated; were this therefore removed by proper means, the remaining vegetable matter would undoubtedly yield a further product of alcohol.

In the attenuation of raw-grain wash, the specific gravity seldom arrives at 1·000; but most commonly stops short at 1·002 or 1·004. When the vinous fermentation comes to an end, the acetous is apt to commence, and to convert a portion of the alcohol into vinegar; a result which is easily ascertained by the increasing specific gravity, sour smell, and acidulous reaction of the wash upon litmus paper, which remains after the paper is heated, showing that the red color is not caused by carbonic acid.

Fermentation proceeds with more uniformity and success in the large tuns of the distiller, than in the experimental apparatus of the chemist; because the body of heat generated in the former case maintains the action. But I have succeeded in obviating this inconvenience in operating upon 80 or 90 gallons, by keeping up the temperature, when it begins to flag, by transmitting hot water through a recurved pipe plunged into the tun.

We have already mentioned that one gallon of spirits, one in ten over-proof, is upon the average generated from 11·04 lbs. of starch sugar; hence we conclude that one pound water-measure of spirits at proof ($= \frac{1}{10}$ imperial gallon) is produced from one pound of the saccharum.

Malt whiskey.—The treatment and produce of malt distilleries are in some respects different from those of raw grain. Having been professionally employed by the proprietors of both, I am prepared to state the peculiarities of the latter, by an example. 500 bushels of ground malt are first mashed with 9000 gallons of water, heated to the temperature of 160° F.: 6000 gallons of worts are drawn off into the coolers, and let down into the fermenting tun at 68°. From 3 to 4 per cent. of a mixture of London porter yeast with quick Scotch barm are added, and well stirred through the mass. At the end of two or three days, in general, the fermentation is finished. On the residuary grains of the malt, from 4500 to 5000 gallons of water at 180° are run, which after proper mashing as before, are drawn off; then 4500 more are poured on, the drainage of which is added to the second. Both of these together, constituting 9000 gallons, are heated next day, and employed for the mashing of 500 bushels of fresh malt. During the fermentation, the wash which was set at the spec. grav. 1·065, comes down to water = 1·000.

The wash is distilled in two stills, appropriated to it, of about 800 gallons capacity each, provided with a rotatory chain apparatus for preventing the lees from adhering to the bottom of the still. Into about 800 gallons of wash 8 lbs. of soap are put. The liquor obtained at this first distillation is called low wines. These low wines are redistilled in the spirit stills; the first and last portions of liquid being more or less blue or milky in color, and rank in flavor, are run into a separate receiver called the *faints-back*;

while the middle portion, constituting in a well-managed distillery, from three fourths to four fifths of the whole, are received into the spirit-back. The faints are mixed with a large quantity of water, and redistilled, in order to free them from the fetid oil derived from the husks of the grain. The interception of this noxious oil may be best effected by a self-regulating bath, between the capital of the still and the refrigeratory, as will be explained in treating of STILLS. The capitals of the common Scotch stills are made from 15 to 20 feet high, in order to prevent the chance of the wash boiling over into the worm; and they are, towards the beginning of the process, struck from time to time with a rod, and by the sound emitted it is known whether they be empty, partially filled, or in danger of an overflow; in which case the fire is damped, by a spout near the furnace door, connected by a leather pipe with an elevated reservoir of water. When very pure spirits are wished for, a third or even a fourth distillation is had recourse to; there being a quantity of water mixed each time with the spirit in the still, to prevent its acquiring a harsh alcoholic flavor.

According to some experienced distillers from raw grain, the mashing temperature of the first liquor should not exceed 140° F.; whereas with malt it may be safely and beneficially 165° or 170°. When rye is used instead of malt, 90 bushels of it are mixed with 190 bushels of raw grain, constituting 280 bushels in whole, for the mashing of which 5200 gallons of water are required. An hour and a half more time is necessary for settling the mashing of the above mixture, than of grain alone. Gin is made in this way.

The distiller of malt whiskey calculates on obtaining two gallons of proof spirits from one bushel of malt, in average years. The highest yield is 20 gallons per quarter of 8 bushels; and the lowest is 16, when the malt and fermentation are indifferent. The best temperature to set the fermenting tun with malt wash is about 70° or 72° F.

When malt is 5*s.* the bushel, 6 bushels at 30*s.* will yield 12 gallons of proof spirits. These cost therefore 2*s.* 6*d.* per gallon for the malt; to which must be added 3*d.* per bushel for the amount of malt duty not returned, or 1½*d.* on the gallon; this added to the Scotch duty of 3*s.* 4*d.* the gallon, makes the price altogether 5*s.* 11½*d.*; besides the expenses in fuel, yeast, labor, and rent, which may be estimated at 8½*d.* per gallon. But 3*d.* may be deducted for what is paid by the dairymen for the spent wash and grains. The total cost, therefore, exclusive of use of capital, is 6*s.* 5*d.* per gallon in Scotland.

The following is the work of a Scotch distillery, where good malt whiskey was made.

One bushel of the malt weighed 35 lbs., or the boll, = 6 bushels, 210 lbs. In mashing each boll of malt, 110 gallons of water were run on it at 160° F. As soon as the fermenting tun of 3000 gallons capacity was charged with the wash at from 64° to 74° F., 2 gallons per cent. of barm were added. When the wash had become attenuated from 1·060 to 1·040, another gallon of barm was introduced.

The temperature of the fermenting wash sometimes rises to 96°, which is, however, an extreme case, and not desirable. When the bubbles of carbonic acid mount in rapid succession, it is reckoned an excellent sign. If the tun be small, and stand in a cool apartment, it should be started at a higher temperature than in the reverse predicament. Should the fermentation be suffered to flag, it is in general a hopeless task to restore vigorous action. Some try the addition of *bubs*, that is, of some wort brought into a state of rapid fermentation in a tub, by a large proportion of yeast, but seldom with much success. Indeed, the law prohibits the addition of any wort to the tun at a later period than 24 hours after it is set; so that if bubs are used afterwards, the distiller is apt to incur a penalty.

The maximum quantity of proof spirits obtained on the great scale at any time from raw grain mixed with from one fourth to one eighth of malt, seems to be 22 gallons per quarter.

By the British laws a distiller is not allowed to brew and distil at the same time; but he must work alternately, one week, for instance, at fermentation, and next week at distillation.

In fermenting solutions of sugar mixed with good yeast, the attenuation has been carried down to 0·984, and even 0·982, that is, in the language of the excise, 16 and 18 degrees below water, from 1·060, the density at which it was originally set in the tun. This was excellent work done on the scale of a great distillery nearly 30 years ago, when distillation from sugar was encouraged, in consequence of bad corn harvests.

In an experiment which I made in 1831, for the information of a committee of the House of Commons, on the use of molasses in the breweries and distilleries, I dissolved 1 cwt. of raw sugar in water, so as to form 74½ gallons, inclusive of 2 gallons of yeast. The specific gravity of the mixture was 1·0593 on the 31st of March. By the 6th of April, that is, in 6 days, the gravity had sunk to 0·992, or 8 degrees under water, which was reckoned a good attenuation, considering the circumstances and the small quantity operated upon. By distillation it afforded at the rate of 14·875 gallons of proof spirits for 100 gallons of the wash.

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When the distillers first worked from sugar, they only obtained upon an average from 1 cwt. 10·09 gallons imp. of proof spirit; but they afterwards got no less than 11·92 imp. gallons.

The following experiment, which I made upon the fermentation of West India molasses into spirits, for the information of the said committee, may prove not uninteresting to my readers. 150 lbs. were dissolved in water and mixed with 2 gallons of yeast, weighing exactly 20 lbs. The wash measured 70 gallons, and had a spec. gravity of 1·0647 at 60° F. In two days the gravity had fallen to 1·0055; in three days to 1·0022; and in five days to 1·001. The temperature was kept up at from 80° to 90° F., during the last two days, by means of a steam pipe, to favor the fermentation. The product of spirits was 11 gallons, and $\frac{35}{100}$ of a gallon. Now 150 lbs. of the above molasses were found to contain of solid matter, chiefly uncrystallizable, 112 lbs. And as 112 lbs. of sugar are estimated by the revenue laws to afford by fermentation 11½ gallons imp. of proof spirit, the result of that experiment upon molasses must be considered satisfactory, bearing in mind that the saccharine substance in molasses has been not only partially decomposed by heat, but is mixed with some of the glutinous or extractive matter of the cane.

Since the alteration of the excise laws relative to distillation in 1825 and 1826, when permission was given to set the wort at lower gravities, the quantity of spirits produced from 1 quarter of corn has been much increased, even up to fully 20 gallons; and the proportion of malt has been much diminished. The latter was soon reduced from three sevenths malt, and four sevenths barley, or two fifths malt and three fifths barley, to one fifth of malt and now to one tenth or even one sixteenth.

A discussion having lately taken place in Ireland between certain persons connected with the distilleries and the officers of the excise, whether, and to what extent, raw grain worts would pass spontaneously into the vinous fermentation, the Board in London requested me to superintend a series of researches in a laboratory fitted up at their office, to settle this important point. I shall content myself here with giving the result of one experiment, out of several, which seems to me quite decisive. Three bushels of mixed grains were taken, consisting of two of barley, one half of oats, and one half of malt, which, being coarsely ground by a hand-mill, were mashed in a new tun with 24 gallons of water at 155°. The mash liquor drawn off amounted to 18 gallons, at the density of 1·0465; and temperature of 82° F. Being set in a new tun, it began to ferment in the course of 12 hours, and in 4 days it was attenuated down to gravity 1·012. This yielded, upon distillation in low wines, 3·22 gallons, and by rectification, in spirits, 3·05; while the quantity equivalent to the attenuation by the tables was 3·31, being an excellent accordance in such circumstances.

The inquisitorial *régime* imposed by law upon our distilleries, might lead a stranger to imagine that our legislators were desirous of repressing by every species of annoyance the fabrication of the fiery liquid which infuriates and demoralizes the lower population of these islands. But alas! credit can be given them for no such moral or philanthropic motive. The necessity of the exchequer to raise a great revenue, created by the wasteful expenditure of the state, on the one hand, and the efforts of fraudulent ingenuity on the other, to evade the payment of the high duties imposed, are the true origin of that *régime*. Examinations in distilleries are constantly making by the officers of excise. There is a survey at 6 o'clock in the morning, when the officers take their accounts and gauges, and make calculations which occupy several hours. At 10 o'clock they again survey, going over the whole premises, where they continue a considerable time, frequently till the succeeding officer comes on duty; at 2 in the afternoon another survey takes place, but not by the same people; at 6 in the evening the survey is repeated; at 10 there comes another survey by an officer who had not been engaged in any of the previous surveys of that day. He is not relieved till 6 o'clock next morning. In addition to these regular inspections, the distilleries are subject to frequent and uncertain visits of the surveyor and general surveyor. "We are never," says Mr. Smith, the eminent distiller of Whitechapel, "out of their hands."*

Before the fermented wort goes into the still, a calculation is made of the quantity of wash drawn from the wash back, and which is first pumped into what is called the wash charger. If the quantity in the wash charger exceeds the quantity in the wash back, the distiller is charged upon the higher quantity; if it contains less, he must pay according to the wash back, as being the larger quantity. When the quantity of wash is all transferred to the charger, the discharge cock of the wash charger is unlocked, and the wash is allowed to be drawn off from the charger into the still, the charging and discharging cock of the still being locked by the officer. There can be no transfer of wash but through the pumps, which are locked also. The first distillation from the wash is worked into the low-wine receiver, which is also a locked up vessel; then of those low wines, the strength and quantity are ascertained by the excise. The account of them affords a comparison with the quantity which the contents of the wash-back had been estimated to produce; they are then pumped from the low wine receiver, through pumps previously locked into the low wine charger, which is also a locked up vessel; from the locked up charger, after the officer has done his duty regarding it, they are allowed to be drawn off into the low wine still, which is a distillation of the second extraction; then that low wine still works into another locked up cask, called the spirit receiver, for the receiving of raw spirits; when that distillation is finished, the officer, attending again on regular notice for that purpose, takes the quantity and strength of the spirits therein, and upon the quantity so ascertained he charges the duty. In distilling low wines, one portion of them goes into the spirit receiver, and a portion into what is called the faint receiver, which is another locked up vessel. These faints are in the next distillation united with the low wines, from the succeeding wash-back on their second distillation, and are worked together; the united produce of these goes partly into the spirit cask, and partly back again into the faint cask. The operation is thus continued till all the backs in the house are emptied.

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* Report of Committee on Molasses, 2198.

There is a kind of ardent spirits manufactured in Holland, vulgarly called Dutch gin, Hollands, and sometimes *geneva*, from *genievre*, the French for juniper, a plant with the essential oil of whose berries it is flavored. One cwt. of ground malt mixed with two cwts. of rye meal are mashed for two hours, with about 450 gallons of water at the temperature of 160° F. The mash drawn off is reduced with cold water till the liquid part has the density of 45 lbs. per barrel, = specific gravity 1·047; and is then put all together into the fermenting back at the temperature of 80° F. One or two gallons of yeast are added. The fermentation soon becomes so vigorous as to raise the heat to 90° and upwards, but it is not pushed far, being generally over in two days, when the gravity of the wash still indicates 12 pounds of saccharum per barrel. By this moderate attenuation, like that practised by the contraband distillers of the Highlands of Scotland, it is supposed that the fetid oil of the husks is not evolved, or at least in very small quantity. The grains are put into the alembic along with the liquid wash, and distilled into low wines, which are rectified twice over, some juniper berries and hops being added at the last distillation. But the junipers are sometimes bruised and put into the mash. The produce of worts so imperfectly fermented, is probably little more than one half of what the British distiller draws from the same quantity of grain. But the cheapness of labor and of grain, as well as the superior flavor of the Skiedam spirits, enables the Dutch distiller to carry on his business with a respectable profit. In opposition to the above facts, Dubrunfaut says that about one third more spirits is obtained in Holland from grain than in France, because a very calcareous spring water is employed in the mashing operation. Were this account well founded, all that the distillers of other countries would have to do would be merely to introduce a portion of chalk into their mash tuns, in order to be on a par with the Dutch. But the statement is altogether a mistake.

In the vine countries, the inferior wines or those damaged by keeping, as also a fermented mash of the pressed grapes, mixed with water, are distilled to form the *eau de vie de Cognac* of the French, called Brandy in this country. It contains less essential oil, and that of a more agreeable flavor, than corn spirits. See BRANDY.

Berzelius says that there are distillers who are guilty of putting a little arsenious acid into the still; that the spirits contain pretty frequently traces of arsenic, which may be detected by adding to them a little muriatic acid, then evaporating off the alcohol, and passing a current of sulphureted hydrogen gas through the residuary liquid, which will give it the characteristic orpiment yellow tinge, arsenic being present. Copper, which is sometimes introduced into distilled grain, or even malt spirits, in consequence of the soap employed in the process of distillation, may be detected best by the brown precipitate which it occasions with ferroprussiate of potash. No arsenic is ever used in this country.

When damaged grain has been mashed in making whiskey, a peculiar oily substance makes its appearance in it. On approaching the nostrils to such whiskey slightly heated, this volatile matter irritates the pituitary membrane and the eyes very powerfully. These spirits have exactly the smell of an alcoholic solution of cyanogene; they intoxicate more powerfully than pure alcohol of equal strength, and produce even temporary phrensy, with subsequent sickness and disordered functions. This volatile body is not cyanogene, though it be so like it, for it forms no such combinations as cyanogene does. It may be extracted from diluted alcohol by agitating it with an unctuous oil, and then distilling the oil along with water. At the end of 3 or 4 months, this volatile matter disappears in a great measure, even when the spirits impregnated with it are enclosed in well-corked bottles; obviously from its undergoing a spontaneous decomposition. It may be preserved much longer in the state of a watery solution.

When acetic ether is added to well purified or clean spirits, such as the distillers call

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* Thomas Smith, Esq., of Whitechapel Road, in Report of Molasses Committee, Part II. p. 149.

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silent whiskey, it gives it somewhat of the flavor of brandy. For this purpose, also, the spirits are rectified from bruised prunes, or the lees of the cognac distilleries, whereby they acquire additional flavor. The astringent taste of old brandy is imitated by the introduction of a little catechu into the British spirits. Burned sugar is employed as a coloring in these imitations.

IV. *Of making whiskey from potatoes.*—This root, in certain localities where it abounds at a moderate price, is an excellent material for fermenting into alcohol. When sound, it possesses from 20 to 25 per cent. of solid substance, of which starch constitutes at least three fourths; hence 100 pounds contain from 16 to 22 pounds of starch susceptible of being saccharified. In the expressed juice there is a small quantity of tartaric acid.

Previously to mashing, potatoes must be first well washed in a horizontal cylindrical cage revolving partially in a trough of water, as will be described in treating of the manufacture of sugar from beet root. They must be then boiled in a close vessel with steam, provided with a perforated bottom a few inches above the real one. The top has an opening with a cover fitted tightly to it; through that the potatoes are introduced; and immediately above the false bottom there is a similar aperture through which the boiled potatoes are taken out. The steam-pipe enters at the top, runs down the side a little way, and terminates in a widened mouth. The large lids are secured by cross bars, the small hole by folds of linen. In the lower valve there are two small holes closed with pins, for inserting a wire to feel whether the potatoes be sufficiently boiled. If so, the steam is immediately stopped off, the lower lid is removed, and the potatoes pulled out with a hook into a tub. They must be immediately made into a homogeneous paste before they get cold. *Fig.* 464 represents, in plan, or horizontal section, the apparatus used in France for this purpose. A B are two cylinders covered with wire cloth, but open at the ends; C C and D D are two pieces of wood fixed on the two axes, in the form of two cones, with the adjoining surfaces truncated; upon which, as also upon iron rings E F, of the same diameter, made fast to the axes, the wire cylinder rests. Of the two wheels G H, the smaller has 18, the greater has 21 teeth. The diameter of each cylinder is 14 inches, the length 18. Above and between the two cylinders, there is a hopper for the reception of the boiled potatoes. This machine triturates 1200 pounds of potatoes per hour. Their paste must be forthwith mashed with some ground wheat or barley, and a proportion of malt; then be set a fermenting.

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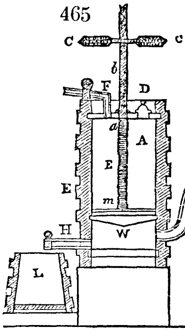

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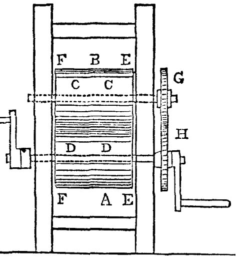


As in the above mode of trituration, the potatoes are apt to cool to such a degree as to obstruct their ready admixture with water, it is better to make them into a paste in the vessel in which they are steamed. The apparatus contrived by Siemens fully answers this end. It consists essentially of a tub A, represented in *fig.* 465, in section. It is cylindrical, and made of planks from 3 to 4 inches thick, joined firmly and steam-tight; the upper and under ends being well secured with iron hoops. The lower part is about 2 inches more in diameter than the upper. About a foot from the bottom, in a circular groove, a cast iron partition W, or disc full of holes, is made fast, which serves the purpose of a searce, the apertures being an inch asunder; above, from $\frac{1}{8}$ to $\frac{1}{10}$ of an inch in diameter, and below, scooped out to half an inch. This disc is half an inch thick in the edges, and five fourths of an inch in the middle.

Through the female screw *a* in the top of the cylinder, there passes the screwed rod *b*, one and a half inches thick, provided at top with a strong cross bar C C, for turning it round. The under end of this rod has a square piece terminating in a short screw, upon which a wrought iron cross is secured by means of a screw nut, so as to stand at right angles to the rod. This cross is composed of two distinct arms; of which one of them is mounted on the upper side with little knives an inch and a half long; the other, upon the under side, with a wire brush, that may be made to rub against the perforated cast iron disc. On the side of the cylinder at E, *fig.* 465, there is a narrow aperture provided with a bung secured by a cross bar, and near the bottom at H there is another like it. Both openings serve for taking out the residuary matter. Through the opening E, the above two arms are introduced; and secured to the square of the rod by the screw nut. In the top there is an opening, D, for putting in the potatoes which may be shut in the same way. From the lid there likewise issues a lateral tube F, which terminates in a tubful of water, for condensing the waste steam. G is the tube connected with the steam boiler, for conducting the steam into the space under the iron disc W.

With this apparatus the potatoes are prepared as follows: when the screw rod is so fixed that the cross touches the disc, the cylinder is to be filled with washed potatoes to within one foot of the top, leaving them some space to expand. The orifice D is to be then closed, and the steam admitted. When the potatoes are boiled enough, two laborers lay hold of the lever handles C C, of the screw rod *b*, and turn it round with the effect of screwing up the spiked cross, and of triturating the potatoes; an operation which may be still more effectually done by screwing it down again. The potato paste is now let off by the plug hole H, into the tub L, where it is mixed with about 30 per cent. of boiling water, and one thousandth part of potash, made caustic with quicklime, in order to dissolve the albuminous matter coagulated by the heat, and give complete fluidity to the mass. The alkali also neutralizes the tartaric acid present. The mashed matter must now be mixed with the crushed malt diffused through 40 or 50 pounds of cold water for every 100 pounds of potatoes, which lowers the temperature to 167°. The wort must be then diligently stirred during two hours; mixed with 40 or 50 pounds of cold water for 100 pounds of potatoes, and, when reduced to the temperature of 77°, put into the fermenting tun along with the proper quantity (3 or 4 per cent.) of yeast. As potatoes readily pass into the acetous fermentation, the admixture of the malt, the mashing, and the cooling should be rapidly performed, while the utmost cleanliness must be observed.

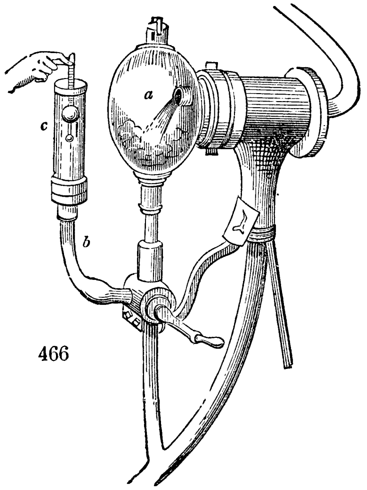
The fermentation is brisk, probably from the agency of the albumen, and furnishes a good head of barm, which answers well for the bakers; 100 pounds of potatoes yield from 18 to 20 pounds measure of spirits, nine elevenths of our excise proof; or about 16 pounds measure of proof, = about $1\frac{2}{3}$ gallons.

It has been observed that after the month of December potatoes begin to yield a smaller product of fermented spirits; and when they have once sprouted or germinated, they afford very little indeed. From the difficulty of keeping and transporting potatoes, distillation from them, even though our laws now permit it, can never become general till some plan be adopted for overcoming these disadvantages. A scheme of this kind, however, has been successfully practised in Vienna, which consists in subjecting the washed potatoes to strong pressure in a perforated chest by a hydraulic or screw press, whereby they lose about three fourths of their weight, and may then be readily dried into a white flour, that may be kept for several years without injury, and transported to considerable distances with comparative ease. This flour, mixed with a moderate quantity of ground malt, and saccharified by mashing with water, at the temperature of 167° F., becomes capable of affording a sweet wort convertible by fermentation either into beer or whiskey.

Horse-chestnuts, according to Hermstaedt, are an eligible material for producing alcohol, as 128 pounds of them afford 100 pounds of meal; which 100 pounds yield, by proper treatment, 34 pounds of spirits, containing 36 per cent. of absolute alcohol, by Richter's tables. Barley to the extent of 10 pounds per 100 should be ground up with them, after they have been boiled in a steam apparatus, not only for the purpose of softening them, but freeing them from their bitter astringent matter. Acorns are productive of alcohol by similar treatment.

The best means hitherto discovered for depriving bad whiskey of its nauseous smell and taste is to pass it through well burned and coarsely pulverized charcoal, distributed as follows in a series of cylindrical casks. Each vessel must have a double bottom, the false one being perforated with conical holes, and placed a few inches above the true. Upon this perforated board a layer of chopped clean straw, one inch thick, is laid; and over the straw, a stratum of small river gravel, the size of large peas. This is to be covered with a pretty thick stratum of the charcoal, previously freed from dirt and dust by washing; upon which a piece of close canvass is to be spread, and pressed down by a thin bed of river sand. The cylinder or cask should be filled with these successive layers to within two inches of its top, and it is then to be closed air-tight. Immediately below the head, a round orifice is pierced in the side, for receiving an overflow tube, which is either screwed rectangularly to another elbow pipe, or is bent (when of block tin) so as to enter tight into an orifice beneath the false bottom of the second cylinder or cask. In this way, the series may be continued to any desired number of vessels; the last discharging the purified spirit into the store-back. The foul spirit must be made to flow into the bottom space of the first cylinder down through a pipe in communication with a charging-back placed upon such an elevated level as to give sufficient pressure to force the spirits up through the series of filters; the supply-pipe being provided with a regulating stop-cock. The spirit may be filtered *downwards* through sand and cloth in its final passage to the receiver. It has been found, with very crude spirits, that eight successive cylinders were required to deprive them entirely of the rank flavor.

Fig. 466 represents one form of the worm-safe, which is a contrivance for permitting trivance for permitting the distiller to observe and note at any period of the distillation the alcoholic strength or the specific gravity of his spirits, without access to the still or the means of purloining the product before it has paid duty. The nose-pipe of the worm-tub terminates in, and is firmly cemented to the side of the glass globe, *a*, from whose bottom the discharge-pipe descends vertically, but has a stop cock upon it, and a branch small pipe *b*, turned up parallel to the former. This branch is surmounted with a glass cylinder, *c*, which, when the stop-cock is opened, gets filled with the spirits, and then receives a hydrometer to show the gravity of the fluid. The stop-cock mechanism is so contrived, that only one full of the small glass cylinder can be obtained at a time.



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The following is the gross produce of the excise duties on British distilled spirits for the United Kingdom annually from 1830 to 1840 inclusive: 1831, 5,196,175*l.*; 1832, 5,163,373*l.*; 1833, 5,258,572*l.*; 1834, 5,287,032*l.*; 1835, 5,073,276*l.*; 1836, 5,485,883*l.*; 1837, 5,006,697*l.*; 1838, 5,451,792*l.*; 1839, 5,363,220*l.*; 1840, 5,208,040*l.* The net produce is very nearly the same. In 1838, 26,486,543 millions of gallons paid duty; in 1839, 25,190,843; and in 1840, 21,859,337. See RUM, SPIRITS, and STILL.

DIVIDIVI, is an indigenous production of Jamaica. Mr. Rootsey obtained a mean produce of 6·625 grs. of leather from 60 grs. of dividivi, while the same quantity of the best Aleppo galls yielded only a mean produce of 4·625. Hence it appears from Sir Humphry Davy's estimate, that the 60 grs. of dividivi contain 3·0475 grs. or 5·079 per cent. of tannin and 60 grs. of galls, on 2·12704 grains, or 345 per cent. Sixty grs. of oak bark yielded only 1·75 grains of leather; whence it follows that it contains but 0·805 of a grain of tannin to the drachm, or not more than 1·34166

DOCIMACY, from the Greek Δοκιμαζω, I prove (*Docimasie*, Fr.; ***Probierkunst***, Germ.); is the art by which the nature and proportions of an ore are determined. This analytical examination was originally conducted in the dry way, the metal being extracted from its mineralizers, by means of heat and certain fluxes. But this method was eventually found to be insufficient and even fallacious, especially when volatile metals were in question, or when the fluxes could absorb them. The latter circumstance became a very serious evil, whenever the object was to appreciate an ore that was to be worked at great expense. Bergmann first demonstrated, in an elaborate dissertation, that the humid analysis was much to be preferred; and since his time the dry way has been consecrated chiefly to the direction of metallurgic operations, or, at least, it has been employed merely in concert with the humid, in trials upon the small scale.

After discovering an ore of some valuable metal, it is essential to ascertain if its quantity and state of combination will justify an adventurer in working the mine, and smelting its products. The metal is rarely found in a condition approaching to purity; it is often disseminated in a mineralizing *gangue* far more bulky than itself; and more frequently still it is combined with simple non-metallic substances, such as sulphur, carbon, chlorine, oxygen, and acids, more or less difficult to get rid of. In these compound states its distinctive characters are so altered, that it is not an easy task either to recognise its nature, or to decide if it can be smelted with advantage. The assayer, without neglecting any of the external characters of the ore, seeks to penetrate, so to speak, into its interior; he triturates it to an impalpable powder, and then subjects it to the decomposing action of powerful chemical reagents; sometimes with the aid of alkalis or salts appropriate to its nature, he employs the dry way by fire alone; at others, he calls in the solvent power of acids with a digesting heat; happy, if after a series of labors, long, varied, and intricate, he shall finally succeed in separating a notable proportion of one or more metals either in a pure state, or in a form of combination such, that from the amount of this known compound, he can infer, with precision, the quantity of fine metal, and thereby the probable value of the mine. The blow-pipe, skilfully applied affords ready indications of the nature of the metallic

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constituents, and is therefore usually the preliminary test. The separation of the several constituents of the ore can be effected, however, only by a chemist, who joins to the most extensive knowledge of the habitudes of mineral substances, much experience, sagacity, and precision, in the conduct of analytical operations. Under the individual metals, as also in the articles METALLURGY, MINES, and ORES, I have endeavored to present such a copious and correct detail of docismastic processes, as will serve to guide the intelligent student through this most mysterious labyrinth of nature and art.

DONARIUM, *a recently discovered metal.*—Dr. Bergemann received through Mr. Krantz a mineral from Brerig in Norway, which is found in the same zircon-syenite that contains wöhlerite and eukolite, and he discovered in it the oxide of a new metal combined with silicic acid. This metal he calls *Donarium*, after the god Donar, and he assigns to it the symbol Do.

The silicate of the oxide of donarium, $Do_2\,O_3\,Si\,O_3+2\,H\,O$, is yellowish red, in some fragments passing into brown, in others into yellow; when scratched or powdered, it is light orange. In thin films it is almost transparent, the thicker ones translucid. Some pieces have a distinctly laminated structure, in others the fracture is more flat, or conchoidal. Its hardness is between that of fluor spar and apatite; its spec. grav.=5·397.

Small films heated in a platina spoon break down into a dark brown mass, which reässumes an orange color when cold: the larger pieces lose their transparency. By heating it in a glass tube, watery vapor is driven off. Fragments held by the platina forceps in the flame of a spirit lamp decrepitate. Heated by the blowpipe on charcoal, it does not melt, a slight vitrification being sometimes observed on the edges, perhaps in consequence of the intermixture of some foreign substance. Fused with soda, the silicic acid is dissolved. The other constituents are seen in the non-transparent mass, by the help of a glass, as small yellow particles. Borax yields a yellow bead, which is colorless when cold. The phosphates produce in the external part of the flame a reddish glass, which is colorless when cold; in the inner part of the flame the bead becomes yellow, and when cold is colorless.

The mineral is readily and completely decomposed by acids, and yields when treated by hydrochloric acid a clear and transparent gelatinous matter. At the same time some carbonic acid is evolved. The color of the solution is deep yellow, like that of a concentrated solution of iron. The mineral is also affected by diluted acids, even by tartaric acid. After having been exposed to a strong heat, the essential parts of the mineral are no longer acted upon even by concentrated acids.

The analysis showed the presence of lime, water, and the new oxide, also some traces of magnesia, manganese, carbonate of soda, and iron.

The oxide of donarium belongs to the class of earthy bodies, and ranks next to zirconia and yttria. The hydrate, which is thrown down by ammonia of a beautiful white color, becomes yellow, and at last yellowish red, losing its hydrate water in the air. By heat the latter is completely removed, and the oxide, which is insoluble in muriatic acid, can be perfectly deprived by this acid of the contained iron. The analysis showed the constituents to be:—

Silicic acid	17·695
Oxide of donarium	71·247
Carbonate of lime	4·042
Oxide of iron	0·310
Magnesia and oxide of manganese	0·214
Potash and a little soda	0·303
Water	6·900
	100·741

The metal is obtained as a black powder, by treating the oxide with potassium. If the alkaline solution be directly poured off and the powder washed with water, it can be kept for from 24 to 36 hours under water without alteration; but if it remains under hot water, a yellowish gray mass is gradually formed, in consequence of oxidation. The black metallic powder forms heavy flocculi, which soon conglomerate and are easily separated by filtration. When in the dried state they assume a metallic lustre when rubbed with an agate; and then can be preserved in this condition for several hours, even in a damp atmosphere, without developing any smell. The specific gravity is nearly =7·35. The powder thrown into a flame burns with a reddish light, and yields the red oxide; so also, if the black powder be heated in a platina spoon, it burns, and moreover appears to glow, but only transitorily. Neither cold nor boiling muriatic acid affects the metal; nitric acid acts not when cold, and but slowly when heated; nitro-muriatic acid readily produces the red oxide, of which a small portion is dissolved; by the application of a few drops of sulphuric acid a sulphate is formed, while at the same time the smell of sulphurous acid is perceived. The grayish yellow

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substance produced by potash water, quickly forms, when heated by itself or moistened with nitric acid, the red oxide. This powder also, when thrown into the flame of a spirit lamp, glows.

Hydrated Oxide of Donarium.—The precipitate produced by ammonia from the muriatic solution of the mineral is, by long digestion with sulphuric acid, converted into sulphate of the oxide of donarium, and from this the hydrated oxide is precipitated by ammonia. The voluminous precipitate, dried at ordinary temperatures, forms yellow gummy masses, the powder of which is reddish. In this condition the substance represents the pure hydrated oxide, which, like oxide of iron, probably combines with different proportions of water. The water is expelled by a slight increase of temperature. The hydrate is dissolved by all acids at common temperatures, and more so when heated. If muriatic acid be employed, no chlorine is developed.

Oxide of Donarium is obtained by heating the hydrate to redness. Its sp. grav. is 5·576, color deep red; its form heavy glittering scales. Finely powdered it is orange; darker when strongly heated, and lighter again when cold. Muriatic acid, nitric acid, aqua regia, and even fluoric acid, have no effect upon the oxide which has been heated to redness. By the continued action of concentrated sulphuric acid it is rendered soluble, if it be afterward mixed with much water. If the oxide, however, be exposed only to that temperature which expels the water from the hydrate, it is slightly acted upon by muriatic acid, without the development of chlorine.

DORNOCK is a species of figured linen of stout fabric, which derives its name from a town in Scotland, where it was first manufactured for table-cloths. It is the most simple in pattern of all the varieties of the diaper or damask style, and therefore the goods are usually of coarse quality for common household wear. It receives the figure by reversing the flushing of the warp and woof at certain intervals, so as to form squares, or oblong rectangles upon the cloth. The most simple of these is a succession of alternate squares, forming an imitation of a checker board or mosaic work. The coarsest kinds are generally woven as tweels of three leaves, where every thread floats over two, and is intersected by the third in succession. Some of the finer are tweels of four or five leaves, but few of more; for the six or seven leaf tweels are seldom or never used, and the eight leaf tweel is confined almost exclusively to damask. See TEXTILE FABRIC.

DRAGON'S BLOOD, (*Sang dracon*, Fr.; *Drachenblüt*, Germ.) is a resinous substance, which comes to us sometimes in small balls about the size of a pigeon's egg, sometimes in rods like the finger, and sometimes like irregular cakes. Its color, in lump, is dark brown red; in powder, bright red; friable; of a shining fracture; sp. grav. 1·196. It contains a little benzoic acid, is insoluble in water, but dissolves readily in alcohol, ether, and oils. It is brought from the East Indies, Africa, South America, as the produce of several trees, the *Dracœna Draco*, the *Pterocarpus santalinus*, *Pterocarpus Draco* and the *Calamus Rotang*.

Dragon's blood is used chiefly for tinging spirit and turpentine varnishes, for preparing gold lacquer, for tooth tinctures and powders, for staining marble, &c. According to Herbenger, it consists of 9·07 parts of red resin, 2 of fat oil, 3 of benzoic acid, 1·6 of oxalate, and 3·7 of phosphate of lime.

DRUGGET is a coarse, but rather slight, woollen fabric, used for covering carpets, and as an article of clothing by females of the poorer classes. It is now-a-days nearly superseded by coarse cotton goods.

DRYING HOUSE. An apartment fitted up in a peculiar manner for drying calicoes and other textile fabrics. Mr. Southworth, of Sharples, a Lancashire bleacher, obtained a patent, in 1823, for the following ingenious arrangement, which has been since generally adopted, with certain modifications, in most of our extensive bleaching and printing works. *Fig.* 467 is a section of the drying-house, where *a* is a furnace and boiler for the purpose of generating steam; it is furnished with a safety valve in the tube *b*, at top, and from this tube the steam main *c* passes down to the floor of the basement story. From this main, a series of steam-pipes, as *d d*, extend over the surface of the floor, and from them heat is intended to be diffused for the purpose of warming the drying-house.

Along the middle of the building a strong beam of timber *e e* extends, and is supported by cast-iron pillars; from this beam to bearings on the side walls, a series of rails are carried in a cross direction, over which rails the wet cloth is to be hung in folds, and the steam or evaporation emitted in drying is allowed to escape through apertures or ventilators in the roof.

The mode in which the cloth is delivered on to the rails, on either side of the beam, will be best understood by reference to the delivering carriage, which is shown with its rollers partly in section.

The wet cloth is first to be coiled upon a roller, and then placed in the carriage, as at *f*, with its pivots bearing upon inclined planes. The carriage is to be placed at the commencement of the rails, running upon the middle beam, and also upon the side-bearings or railways extending along the side walls of the building, parallel to and upon a level with the same beam. It is made to travel by means of an endless band passing over two riggers, *g* and *h*, in *fig.* 467, and over pulleys and a band-wheel attached to the carriage, as will be explained. The rigger *g*, which moves this endless band, is actuated by bevel geer, seen at *i*, which is put in motion by a pinion at the end of a revolving shaft leading from a steam engine.

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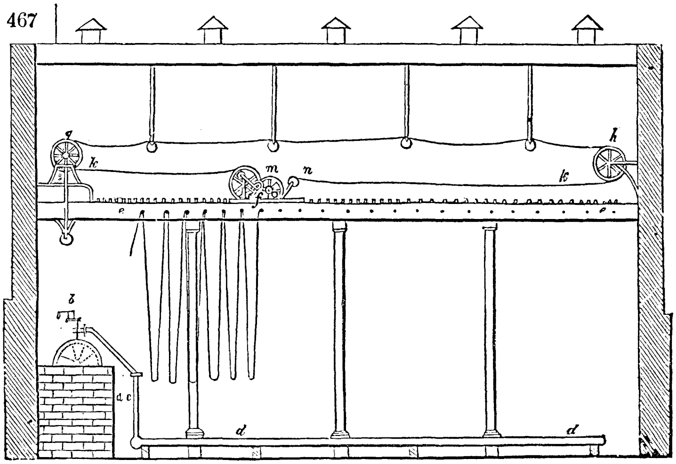


In the same *fig.*, *k k* is the endless band passing over a pulley under the band-wheel and over the pulley *n*, by which it will be perceived that the traversing of the band, as described, would cause these pulleys and wheels to revolve. On the axle of the band-wheel *m*, there is a drum against which the roll of wet cloth *f* presses, and as this drum revolves, the roll of wet cloth is, by its friction, made to turn in a contrary direction, and to deliver off the cloth on to the periphery of the drum, whence it passes over a roller and descends to the rails. Upon the end of the axle of the band wheel *m*, there is a pinion which takes into the teeth of the large wheel, and upon the axle of this large wheel there is a pinion that actuates the intermediate wheel which turns another toothed wheel. This last-mentioned toothed wheel takes into cogs upon the side railway, and hence, as the train of wheels moves round, the carriage to which the wheels are attached is slowly impelled forward.

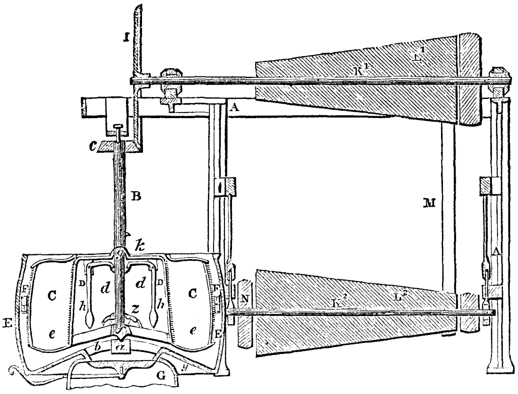
As soon as the wheels begin to move, and the carriage to advance, the wet cloth begins to uncoil, and to pass down over the first roller; a small roller attached to the carriage, as it passes over the rails in succession, holds the cloth against each rail for a short space of time, and prevents it from slipping, by which means the cloth descends in folds or loops between the rails, and is thereby made to hang in a series of folds or loops, as shown in the figure.

It will be perceived that as the pivots of the cloth roller *f* bear upon inclined planes, the roller will continually slide down as the cloth diminishes in bulk, keeping in contact with the drum, and delivering the cloth from the roller on to the several rails, as described.

In order to stop the carriage in any part of its course, or to adjust any of the folds of the cloth, a man is usually placed upon the platform travelling with the carriage, over which he has perfect command. This apparatus may be also employed for taking the cloth when dried off the rails; in which case the carriage must be made to travel backward, and by first guiding the end of the cloth on to the roller *f*, and then putting the wheels in a retrograde motion, the cloth will be progressively coiled upon the roller *f*, in a similar way to that by which it was uncoiled.

DRYING MACHINE (CENTRIFUGAL), (*Hydro-extracteur ; Machine à essorer*, Fr.)—By this contrivance, Pentzoldt was enabled to deprive all kinds of wet clothes in a few minutes of their moisture, without compression or heat. Kelly, a dyer, and Alliott, a bleecher, have since obtained a patent for the above machine with improvements. *Fig.* 468 represents a partial section of the machine. A, A, is the frame; B, the vertical shaft turning in the step *a*, fixed on the bridge *b*. This shaft bears on its upper part a friction cone *c*, from which it receives its movement of rotation, as will be shown presently; c is a drum containing two concentric compartments *d e*, of the form represented in the figure; this drum moves freely upon the shaft B, and

468.



rests when it is not in motion upon two conical projections *f*, *g*, which form a part of the shaft. These two compartments are each composed mainly of metal, and their sides consist of tinned iron wire coiled circularly at very small distances from each other, and soldered together crosswise by small slips of metal. The top, which covers the inner compartment *d*, is secured by bolts and screws to a circle of iron which retains the wire sides of the same metal, but that which serves as a cover to the little compartment *e*, in which alone the goods are placed, is disposed so that it may be removed with ease, when these are to be introduced or withdrawn. It is furnished with an outer and inner border, disposed so that when the top is fixed the inner border presses upon the convex circumference of the central compartment, while the exterior border falls outside of the edges of the other compartment. While the machine is at work, the second plate is maintained in its place by pins or bolts, not shown in the figure.

The sides of the outer compartment *d*, are connected with the bottom by means of a prolongation of cross bands of metal which unite the wires and are riveted or soldered to the two outer plates. The wires of the interior compartment are attached by an iron hoop, to which they are riveted and soldered, and are united to the bottom plate by means of a rim upon this plate; a rim somewhat flattened upon the sides which are riveted and soldered.

D, is a regulator suspended in the inner compartment *d*, and whose two branches *h*, *h*, are loaded. These two branches having room to play around the bolts which serve as points of attachment, and which are fixed to the upper plate, terminate in kneed branches whose extremities rest upon a rope *g*, which projects from the shaft. E, is an exterior envelope secured to the frame A, A. It encloses the whole drum except at top, and serves to catch the water thrown out of the goods. At *y* there is a stopcock for the discharge of this water, and the bottom contains besides the end of a pipe by which hot air is introduced.

The vertical shaft B receives a movement of rotation and carries with it the drum. The more rapid this movement is the more does the centrifugal force tend to expel the water contained in the clothes or yarn to be dried. But as this force might also displace the central shaft, if the weight was not rightly distributed in the drum, and cause the dislocation of the machine when the great velocity requisite for quick drying is given to it, the regulator D is tested to prevent accident. The branches of this regulator spread wider the more the velocity is increased, and raise consequently the drum C above the conical enlargements, which permits the drum to be somewhat misplaced and to rectify its position conformably to the inequalities of its load, so that its centre of gravity may always coincide with its centre of rotation. The drum is connected with the shaft as is shown in *z*, leaving it free to take the requisite adjustment. To hinder it from rising too suddenly, a spiral spring *k* is fixed over the shaft immediately above the conical enlargement *g*. In order to maintain the equilibrium more certainly, the apparatus is surrounded with a hollow crown F, half filled with water, and if during the revolution of the machine the weight of the goods predominates on one side, that of the water which accumulates on the other side serves the more to counterbalance it. The effect of this crown may be increased by dividing it into two compartments or more. G, is a large pipe by which steam or hot air is introduced into the belly of the drum, which is pierced in this place with a great number of small holes to receive it.

The rotary movement is transmitted to the drum in the following way.

I is a conical disc mounted upon the extremity of a shaft which actuates the cone C and the shaft B by means of friction; L is a cone fixed upon the extremity of the shaft. K L "is another cone of the same dimension, but whose base fronts the top of the other and which is placed on the shaft K" commanded by the prime mover. M is the belt which embraces the two cones, and whose lateral displacement, effected by means of a fork, permits the velocity of the machine to be regulated at pleasure. N is the pulley which directly receives the movement. In place of a single friction disc I, another may be employed, if judged necessary, and placed between the two, an additional friction pole in order better to equalize the friction. In this case the disc and additional cone should turn freely upon their own shafts. We may also adopt another arrangement for the bottom of the vertical shaft. The shaft immediately above the step is surrounded by a loose rim, around which a certain quantity of lead shot, or other granular matter, is contained in the rim in the box which serves for the step. The top of this box is pierced with an opening, into which, when the machine is at rest, a cord connected with the shaft sinks, controlled by the shaft, and when the drum is raised by the action of the regulator D, this cord quits its place, which allows the shaft to displace the shot a little, and to take a position conformably to the point of the centre of gravity.

But after all great attention should be paid to the proper working of the machine.

DUCTILITY (*Streckbarkeit*, Germ.) is the property of being drawn out in length without breaking, possessed in a pre-eminent degree by gold and silver, as also by many other metals, by glass in the liquid state, and by many semifluid resinous and gummy substances. The spider and the silk-worm exhibit the finest natural exercise of ductility upon the peculiar viscid secretions from which they spin their threads. When a body can be readily extended in all directions under the hammer, it is said to be malleable, and when into fillets under the rolling press, it is said to be laminable.

Table of the ductility and malleability of Metals.

Metals ductile and malleable in alphabetical order.	Brittle metals in alphabetical order.	Metals in the order of their wire-drawing ductility.	Metals in the order of their laminable ductility.
Cadmium.	Antimony.	Gold.	Gold.
Copper.	Arsenic.	Silver.	Silver.
Gold.	Bismuth.	Platinum.	Copper.
Iron.	Cerium. ?	Iron.	Tin.
Iridium.	Chromium.	Copper.	Platinum.
Lead.	Cobalt.	Zinc.	Lead.
Magnesium.	Columbium.	Tin.	Zinc.
Mercury.	Iridium.	Lead.	Iron.
Nickel.	Manganese.	Nickel.	Nickel.
Osmium.	Molybdenum.	Palladium. ?	Palladium. ?
Palladium.	Osmium.	Cadmium. ?	Cadmium. ?
Platinum.	Rhodium.		
Potassium.	Tellurium.		
Silver.	Titanium.		
Sodium.	Tungsten.		
Tin.	Uranium.		
Zinc.			

There appears to be, therefore, a real difference between ductility and malleability; for the metals which draw into the finest wire are not those which afford the thinnest leaves under the hammer or in the rolling press. Of this fact iron affords a good illustration. Among the metals permanent in the air, 17 are ductile and 16 are brittle. But the most ductile cannot be wire-drawn or laminated to any considerable extent without being annealed from time to time during the progress of the extension, or rather the sliding of the particles alongside of each other, so as to loosen their lateral cohesion.

DUNGING, in calico-printing, is the application of a bath of cowdung, diffused through hot water, to cotton goods in a particular stage of the manufacture. Dunging and scouring are commonly alternated, and are two of the most important steps in the process. The operation of dunging has for its objects:—

1. To determine the entire combination of the aluminous sub-salts with the stuffs, by

separating almost all the acetic acid which was not volatilized in the stove-drying of the mordant.

2. To dissolve and carry off from the cloth a portion of the thickening matters.

3. To separate from the cloth the part of the mordant that is uncombined, and merely mixed mechanically with the gum or starch.

4. To prevent, by the peculiar action of the dung, the uncombined mordant, as well as the acetic acid with which the bath is apt to get loaded, from affecting the blank parts of the cloth, or being injurious to the mordant.

The aluminous base or mordant on the cloth, more or less neutralized by the dunging, is next subjected to the dash-wheel or fulling mill, where by the stream of water the remainder of the thickening and other impurities are washed away.

No very exact analysis has been made of cowdung. Morin's, which is the most recent and elaborate, is as follows:—

Water	70·00
Vegetable fibre	24·08
Green resin and fat acids	1·52
Undecomposed biliary matter	0·60
Peculiar extractive matter (*bubuline*)	1·60
Albumen	0·40
Biliary resin	1·80

According to M. Kœchlin's practical knowledge on the great scale, it consists of a moist fibrous vegetable substance, which is animalized, and forms about one tenth of its weight; 2. of albumen; 3. of animal mucus; 4. of a substance similar to bile; 5. of muriate of soda, muriate and acetate of ammonia, phosphate of lime and other salts; 6. of benzoin or musk.

Probably the hot water in which the calico-printer diffuses the dung exerts a powerful solvent action, and in proportion as the uncombined mordant floats in the bath it is precipitated by the albumen, the animal mucus, and the ammoniacal salts; but there is reason to think that the fibrous matter in part animalized or covered with animal matter, plays here the principal part; for the great affinity of this substance for the aluminous salts is well known.

All practical men are aware that the affinity of cotton for alumina is increased by its combination with oil or animal substances, to such a degree as to take it from the dung bath; which would not be possible without this combination. It would therefore appear that the principal function of dunging is to hinder the uncombined mordant, diffused in the dung bath, from attaching itself to the unmordanted portion of the cloth, as already observed; for if we merely wished to abstract the thickening stuffs, or to complete by the removal of acetic acid the combination of the aluminous base with the goods, dung would not be required, for hot water would suffice. In fact, we may observe, that in such cases the first pieces passed through the boiler are fit for dyeing; but when a certain number have been passed through, the mordant now dissolved in the water is attracted to the white portions of the cloth, while the free acid impoverishes the mordanted parts, so that they cannot afford good dyes, and the blank spaces are tarnished.

The cowdung may be in some measure replaced by bran, but not with perfect success. The former both answers the purpose better and is cheaper. The bran is only preferred for the most delicate yellows, for cochineal pinks and lilachs, to which the dung may sometimes impart a greenish cast. It is to be presumed that the action of the bran in this process has much analogy with that of the dung, and that the ligneous fibre is the most active constituent; with which the gluten and mucilage co-operate, no doubt, in seizing the aluminous salts.

It seems to be ascertained that the mordant applied to the cloth does not combine entirely with it during the drying; that this combination is more or less perfect according to the strength of the mordants, and the circumstances of the drying; that the operation of dunging, or passing through hot water, completes the combination of the cloth with the aluminous base now insoluble in water; that this base may still contain a very minute quantity of acetic acid or sulphate of alumina; that a long ebullition in water impoverishes the mordant but a little; and that even then the liquid does not contain any perceptible quantity of acetate or subsulphate of alumina.

The manner of immersing the goods, or passing them through the dung bath, is an important circumstance. They should be properly extended and free from folds, which is secured by a series of cylinders.

The cistern is from 10 to 12 feet long, 4½ feet wide, and 6 or 8 feet deep. The piece passes alternately over the upper rollers and under rollers near the bottom. There are two main squeezing rollers at one end, which draw the cloth through between them. Whenever the goods come out of the bath they are put into the dash-wheel

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The immersion should take place as fast as possible, for the moment the hot water penetrates the mordanted cloth, the acetic acid quits it; and, therefore, if the immersion was made slowly or one ply after another, the acid as well as the uncombined mordant become free, would spread their influence, and would have time to dissolve the aluminous subsalts now combined with the cloth; whence inequalities and impoverishment of the colors would ensue.

It is difficult to determine the number of pieces which may be passed through a given quantity of dung and water. This depends upon the state of the mordants, whether they are strong or acid, and on the quantity of the surface covered with the figures. The number varies usually from 20 to 60 pieces, for from 240 to 300 gallons of water and 6 gallons of dung. The time of the immersion varies with the concentration of the mordants, and the nature of their thickening. The temperature must be regulated by the same circumstances; for starch or flour paste a much warmer bath is needed than for gum. The heat varies usually from 130° to 212° F. When the printing is heavy and the thickening is starch or flour, the goods are usually twice dunged, with two washings between the two dungs. A strong acid mordant is more difficult to dung and to wash than a neutral mordant, especially when it is to receive the madder dye. Sometimes a little chalk is added to the bath, when the goods have been padded in an acid mordant. Too much dung is injurious to weak mordants, as well as to pinks. It has also been remarked that a mordant when neutralized does not produce as brilliant tints, especially yellows. The latter are obtained of a finer shade when, instead of dunging, they are exposed for an hour in a stream of water, provided its temperature is not too low. In winter they are passed through a slightly chalky water, then washed at the wheel, and dyed in quercitron or weld.

A very able and learned memoir upon this subject, by M. Penot, Professor of Chemistry, appeared in the Bulletin of the Society of Mulhausen, in October, 1834, with an ingenious commentary upon it, under the title of a Report by M. Camille Kœchlin, in March, 1835.

Experience has proved that dunging is one of the most important steps in the process of calico printing, and that if it be not well performed the dyeing is good for nothing. Before we can assign its peculiar function to the dung in this case, we must know its composition. Fresh cow's dung is commonly neutral when tested by litmus paper; but sometimes it is slightly alkaline, owing, probably, to some peculiarity in the food of the animal.

The total constituents of 100 parts of cow dung are as follows: Water, 69·58; bitter matter, 0·74; sweet substance, 0·93; chlorophylle, 0·28; albumine, 0·63; muriate of soda, 0·08; sulphate of potash, 0·05; sulphate of lime, 0·25; carbonate of lime, 0·24; phosphate of lime, 0·46; carbonate of iron, 0·09; woody fibre, 26·39; silica, 0·14; loss, 0·14.

In dunging calicoes the excess of uncombined mordant is in part attracted by the soluble matters of the cow's dung, and forms an insoluble precipitate, which has no affinity for the cloth, especially in presence of the insoluble part of the dung, which strongly attracts alumina. The most important part which that insoluble matter plays, is to seize the excess of the mordants, in proportion as they are dissolved by the water of the bath, and thus to render their reaction upon the cloth impossible. It is only in the deposite, therefore, that the matters carried off from the cloth by the dung are to be found.

M. Camille Kœchlin ascribes the action of cow dung chiefly to its albuminous constituent, combining with the alumina and iron, of the acetates of these bases dissolved by the hot water of the bath. The acids consequently set free, soon become evident by the test of litmus paper, after a few pieces are passed through, and require to be got rid of either by a fresh bath or by adding chalk to the old one. The dung thus serves also to fix the bases on the cloth, when used in moderation. It exercises likewise a disoxydating power on the iron mordant, and restores it to a state more fit to combine with coloring matter.

DYEING, (*Teinture*, Fr.; *Färberei*, Germ.) is the art of impregnating wool, silk, cotton, linen, hair, and skins, with colors not removable by washing, or the ordinary usage to which these fibrous bodies are exposed when worked up into articles of furniture or raiment. I shall here consider the general principles of the art, referring for the particular dyes, and peculiar treatment of the stuffs to be dyed, to the different tinctorial substances in their alphabetical places; such as cochineal, indigo, madder, &c.

Dyeing is altogether a chemical process, and requires for its due explanation and practice an acquaintance with the properties of the elementary bodies, and the laws which regulate their combinations. It is true that many operations of this, as of other chemical arts, have been practised from the most ancient times, long before any just views were entertained of the nature of the changes that took place. Mankind, equally in the rudest and most refined state, have always sought to gratify the love of distinction by staining their dress, sometimes even their skin, with gaudy colors. Moses speaks of raiment dyed blue, and purple, and scarlet, and of sheep skins dyed red; circumstances which indicate no small degree of tinctorial skill. He enjoins purple stuffs for the works of the tabernacle and the vestments of the high priest.

In the article Calico Printing, I have shown from Pliny that the ancient Egyptians cultivated that art with some degree of scientific precision, since they knew the use of mordants, or those substances which, though they may impart no color themselves, yet enable white robes (*candida vela*) to absorb coloring drugs (*colorem sorbendibus medicamentis*). Tyre, however, was the nation of antiquity which made dying its chief occupation and the staple of its commerce. There is little doubt that purple, the sacred symbol of royal and sacerdotal dignity, was a color discovered in that city, and that it contributed to its opulence and grandeur. Homer marks no less the value than the antiquity of this dye, by describing his heroes as arrayed in purple robes. Purple habits are mentioned among the presents made to Gideon by the Israelites from the spoils of the kings of Midian.

The juice employed for communicating this dye was obtained from two different kinds of shell-fish, described by Pliny under the names of *purpura* and *buccinum;* and was extracted from a small vessel, or sac. in their throats, to the amount of only one drop from each animal. A darker and inferior color was also procured by crushing the whole substance of the buccinum. A certain quantity of the juice collected from a vast number of shells being treated with sea-salt was allowed to ripen for three days; after which it was diluted with five times its bulk of water, kept at a moderate heat for six days more, occasionally skimmed, to separate the animal membranes, and when thus clarified was applied directly as a dye to white wool, previously prepared for this purpose by the action of lime-water, or of a species of lichen called fucus. Two operations were requisite to communicate the finest Tyrian purple; the first consisted in plunging the wool into the juice of the purpura: the second, into that of the buccinum. Fifty drachms of wool required one hundred of the former liquor, and two hundred of the latter. Sometimes a preliminary tint was given with coccus, the kermes of the present day, and the cloth received merely a finish from the precious animal juice. The colors, though probably not nearly so brilliant as those producible by our cochineal, seem to have been very durable, for Plutarch says, in his *Life of Alexander*, (chap. 36,) that the Greeks found in the treasury of the King of Persia a large quantity of purple cloth, which was as beautiful as at first, though it was 190 years old.

The difficulty of collecting the purple juice, and the tedious complication of the dyeing process, made the purple wool of Tyre so expensive at Rome, that in the time of Augustus a pound of it cost nearly 30*l*. of our money.[†] Notwithstanding this enormous price, such was the wealth accumulated in that capital, that many of the leading citizens decorated themselves in purple attire, till the emperors arrogated to themselves the privilege of wearing purple, and prohibited its use to every other person. This prohibition operated so much to discourage this curious art as eventually to occasion its extinction, first in the western and then in the eastern empire, where, however, it existed in certain imperial manufacturies till the eleventh century.

Dyeing was little cultivated in ancient Greece; the people of Athens wore generally woollen dresses of the natural color. But the Romans must have bestowed some pains upon this art. In the games of the circus parties were distinguished by colors. Four of these are described by Pliny, the green, the orange, the gray, and the white. The following ingredients were used by their dyers. A crude native alum mixed with copperas, copperas itself, blue vitriol, alkanet, lichen rocellus, or archil, broom, madder, woad, nutgalls, the seed of pomegranate, and of an Egyptian acacia.

Gage, Cole, Plumier, Reaumur, and Duhamel have severally made researches concerning the coloring juices of shell-fish caught on various shores of the ocean, and have succeeded in forming a purple dye, but they found it much inferior to that furnished by other means. The juice of the buccinum is at first white; it becomes by exposure to air of a yellowish green bordering on blue; it afterwards reddens, and finally changes to a deep purple of considerable vivacity. These circumstances coincide with the minute description of the manner of catching the purple-dye shell-fish which we possess in the work of an eye-witness, Eudocia Macrembolitissa, daughter of the Emperor Constantine VIII., who lived in the eleventh century.

The moderns have obtained from the New World several dye-drugs unknown to the ancients; such as cochineal, quercitron, Brazil wood, logwood, annatto; and they have

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[*] "Among other things, there was purple of Hermione (?) to the amount of five thousand talents. (Plutarch's Lives, translated by Langhorne, Wrangham's edition, vol. v. p. 240.) Horace celebrates the Laconian dye in the following lines:—

Nec Laconicas mihi
Trahunt honestæ purpuras clientæ.
(Carm. lib. ii., Ode 18.)

[†] Pliny says that a pound of the double-dipped Tyrian purple was sold in Rome for a hundred crowns.

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discovered the art of using indigo as a dye, which the Romans knew only as a pigment. But the vast superiority of our dyes over those of former times must be ascribed principally to the employment of pure alum and solution of tin as mordants, either alone or mixed with other bases; substances which give to our common dye-stuffs remarkable depth, durability, and lustre. Another improvement in dyeing of more recent date is the application to textile substances of metallic compounds, such as Prussian blue, chrome yellow, manganese brown, &c.

Indigo, the innoxious and beautiful product of an interesting tribe of tropical plants, which is adapted to form the most useful and substantial of all dyes, was actually denounced as a dangerous drug, and forbidden to be used, by our parliament in the reign of Queen Elizabeth. An act was passed authorizing searchers to burn both it and log-wood in every dye-house where they could be found. This act remained in full force till the time of Charles II.; that is, for a great part of a century. A foreigner might have supposed that the legislators of England entertained such an affection for their native woad, with which their naked sires used to dye their skins in the old times, that they would allow no outlandish drug to come in competition with it. A most instructive book might be written illustrative of the evils inflicted upon arts, manufactures, and commerce, in consequence of the ignorance of the legislature.*

Colors are not, properly speaking, material; they are impressions which we receive from the rays of light reflected, in a decomposed state, by the surfaces of bodies. It is well known that a white sunbeam consists of an indeterminate number of differently colored rays, which being separated by the refractive force of a glass prism, form the solar spectrum, an image distinguishable into seven sorts of rays; the red, orange, yellow, green, blue, indigo, and violet. Hence, when an opaque body appears colored, for example, red, we say that it reflects the red rays only, or in greatest abundance, mixed with more or less of the white beam, which has escaped decomposition. According to this manner of viewing the coloring principle, the art of dyeing consists in fixing upon stuffs, by means of corpuscular attraction, substances which act upon light in a different manner from the surfaces of the stuffs themselves. The dyer ought, therefore, to be familiar with two principles of optics; the first relative to the mixture of colors, and the second to their simultaneous contrast.

Whenever the different colored rays, which have been separated by the prism, are totally reunited, they reproduce white light. It is evident, that in this composition of light, if some rays were left out, or if the colored rays be not in a certain proportion, we should not have white light, but light of a certain color. For example; if we separate the red rays from the light decomposed by a prism, the remaining colored rays will form by their combination a peculiar bluish green. If we separate in like manner the orange rays, the remaining colored rays will form by their combination a blue color. If we separate from the decomposed prismatic light the rays of greenish yellow, the remaining colored rays will form a violet. And if we separate the rays of yellow bordering on orange, the remaining colored rays will form by their union an indigo color.

Thus we see that every colored light has such a relation with another colored light that, by uniting the first with the second, we reproduce white light; a relation which we express by saying that the one is the complement of the other. In this sense, red is the complementary color of bluish green; orange, of blue; greenish yellow, of violet; and orange yellow, of indigo. If we mix the yellow ray with the red, we produce orange; the blue ray with the yellow, we produce green; and the blue with the red, we produce violet or indigo, according as there is more or less red relatively to the blue. But these tints are distinguishable from the orange, green, indigo, and violet of the solar spectrum, because when viewed through the prism they are reduced to their elementary compound colors.

If the dyer tries to realize the preceding results by the mixture of dyes, he will succeed only with a certain number of them. Thus, with red and yellow he can make orange; with blue and yellow, green; with blue and red, indigo or violet. These facts, the results of practice, have led him to conclude that there are only three primitive colors; the red, yellow, and blue. If he attempts to make a white, by applying red, yellow, and blue dyes in certain quantities to a white stuff, in imitation of the philosopher's experiment on the synthesis of the sunbeam, far from succeeding, he will deviate still further from his purpose, since the stuff will by these dyes become so dark colored as to appear black.

The fact must not, however, lead us to suppose that in every case where red, yellow, and blue are applied to white cloth, black is produced. In reality, when a little ultramarine, cobalt blue, Prussian blue, or indigo, is applied to goods with the view of giving them the best possible white, if only a certain proportion be used, the goods will appear whiter after this addition than before it. What happens in this case? The violet blue forms, with the brown yellow of the goods, a mixture tending to white, or less colored than the yellow of the goods and the blue together were. For the same reason, a mixture of Prussian blue and cochineal pink has been of late years used in the whitening or the azuring of silks, in preference to a pure blue; for on examining closely the color of the silk to be neutralized, it was found by the relations of the complementary colors, that the violet was more suitable than the indigo blue formerly used. The dyer should know, that when he applies several different coloring matters to stuffs, as yellow and blue, for example, if they appear green, it is because the eye cannot distinguish the points which reflect the yellow from those which reflect the blue; and that, consequently, it is only where the distinction is not possible, that a mixture or combination appears. When we examine certain gray substances, such as hairs, feathers, &c., with the microscope, we see that the gray color results from black points disseminated over a colorless or slightly colored surface. In reference to compound colors, this instrument might be used with advantage by the dyer.

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* Author, in Penny Cyclopedia.

The dyer should be acquainted also with the law of the simultaneous contrast of colors. When the eye views two colors close alongside of each other, it sees them differing most in their optical composition, and in the height of their tone, when the two are not equally pale or full-bodied. They appear most different as to their optical composition, when the complementary of the one of them is added to the color of the other. Thus, put a green zone alongside of an orange zone; the red color complementary of green, being added to the orange, will make it appear redder; and in like manner the blue, complementary of orange, being added to the green, will make it appear more intensely blue. In order to appreciate these differences, let us take two green stripes and two orange stripes, placing one of the green stripes near one of the orange: then place the two others so that the green stripe may be at a distance from the other green stripe, but on the same side, and the orange at a distance from the other orange, also on the same side.

As to the contrast in the height of the tone, we may satisfy ourselves by taking the tones No. 1, No. 2, No. 15, and No. 16, from a graduated pallet of reds: for example, by placing No. 2 and No. 15 close alongside, putting No. 1 at a distance from No. 2 on the same side, and No. 16 at a distance from No. 15 on the same side,—we shall see (if the pallet is sufficiently lowered in tone) No. 2 equal to No. 1, and No. 15 equal to No. 16; whence it follows that No. 2, by the vicinity of No. 15, will appear to have lost some of its color; while No. 15 will appear to have acquired color. When black or gray figures are printed upon colored grounds, these figures are of the color complementary of the ground. Consequently, in order to judge of their color, we must cut out spaces in a piece of gray or white paper, so as to allow the eye to see nothing but the figures; and if we wish to compare figures of the same color, applied upon grounds of different colors, we can judge rightly of the figures only by insulating them from the grounds.

The relations of dyeing with the principles of chemistry, constitute the theory of the art, properly speaking; this theory has for its basis, the knowledge—1. of the species of bodies which dyeing processes bring into contact; 2. of the circumstances in which these species act; 3. of the phenomena which appear during their action; and 4. of the properties of the colored combinations which are produced. These generalities may be specified under the ten following heads:—

1. The preparation of the stuffs to be dyed, whether fibres, yarn, or cloth; under the heads of ligneous matter, cotton, hemp, flax; and of the animal matters, silk and wool.
2. The mutual action of these stuffs, and simple bodies.
3. The mutual action of these stuffs, and acids.
4. The mutual action of these stuffs, and salifiable bases, as alumina, &c.
5. The mutual action of these stuffs, and salts.
6. The mutual action of these stuffs, and neutral compounds not saline.
7. The mutual action of these stuffs, and of one or more definite compounds.
8. Of dyed stuffs considered in reference to the fastness of their color, under the influence of heat, light, water, oxygen, air, boilings with soap, and reagents.
9. Of dyeing, considered in its connexions with chemistry.
10. Of dyeing, considered in its relations with caloric, mechanics, hydraulics, and optics.

1. The preparation of stuffs.

The operations to which stuffs are subjected before dyeing, are intended—1. to separate from them any foreign matters; 2. to render them more apt to unite with the coloring tinctures which the dyer proposes to fix upon them, in order to give them a more agreeable, or more brilliant aspect, or to lessen their tendency to assume a soiled appearance by use, which white surfaces so readily do. The foreign matters are either naturally inherent in the stuffs, or added to them in the spinning, weaving, or other manipulation of manufacture. The ligneous fibres must be freed from the colored azotized varnish on their surface, from a yellow coloring matter in their substance, from some lime and iron, from chlorophylle or leaf-green, and from pectic acid; all natural combinations. Some of these principles require to be oxygenized before alkaline leys can cleanse them, as I have stated in the article BLEACHING, which may be consulted in reference to this subject. See also SILK and WOOL. A weak bath of soda has the property of preparing wool for taking on a uniform dye, but it must be well rinsed and aired before being put into the dye-vat.

2. Mutual action of stuffs and simple bodies.

Stuffs chemically considered being composed of three or four elements, already in a state of reciprocal saturation, have but a feeble attraction for simple substances. We know in fact, that the latter combine only with each other, or with binary compounds, and that in the greater number of cases where they exert an action upon more complete compounds, it is by disturbing the arrangement of their elements, and not by a resulting affinity with the whole together.

3, 4. Although stuffs may in a general point of view be considered as neutral in relation to coloring reagents, yet experience shows that they are more disposed to combine with acid than with alkaline compounds; and that consequently their nature seems to be more alkaline than acid. By steeping dry wool or other stuff in a clean state in an alkaline or acid solution of known strength, and by testing the liquor after the stuff is taken out, we shall ascertain whether there be any real affinity between them, by the solution being rendered more dilute in consequence of the abstraction of alkaline or acid particles from it. Wool and silk thus immersed, abstract a portion of both sulphuric and muriatic acids; but cotton and flax imbibe the water, with the rejection of a portion of the acid. The acid may be again taken from the stuffs by washing them with a sufficient quantity of water.

5. The affinity between saline bodies and stuffs may be ascertained in the same way as that of acids, by plunging the dry stuffs into solutions of the salts, and determining the density of the solution before the immersion, and after withdrawing the stuffs. Wool abstracts alum from its solution, but it gives it all out again to boiling water. The sulphates of protoxyde of iron, of copper, and zinc, resemble alum in this respect. When silk is steeped for some time in solution of protosulphate of iron, it abstracts the oxyde, gets thereby dyed, and leaves the solution acidulous. Wool put in contact with cream of tartar decomposes a portion of it; it absorbs the acid into its pores, and leaves a neutral salt in the liquor. The study of the action of salts upon stuffs is at the present day the foundation of the theory of dyeing; and some of them are employed immediately as dye-drugs.

6. Mutual action of stuffs, and neutral compounds not saline.

Several sulphurets, such as those of arsenic, lead, copper, antimony, tin, are susceptible of being applied to stuffs, and of dyeing them in a more or less fast manner. Indigo, hematine, breziline, carmine, and the peculiar coloring principles of many dyes belong to this division.

7. Mutual action of goods with one or more definite compounds, and dye-stuffs.

I shall consider here in a theoretical point of view, the most general results which a certain number of organic coloring matters present, when applied upon stuffs by the dyer.

Indigo. This dye-drug, when tolerably good, contains half its weight of indigotine. The cold vat is prepared commonly with water, copperas, indigo, lime, or sometimes carbonate of soda, and is used almost exclusively for cotton and linen; immersion in acidulated water is occasionally had recourse to for removing a little oxyde of iron which attaches itself to the cloth dyed in this vat.

The indigo vat for wool and silk is mounted exclusively with indigo, good potashes of commerce, madder, and bran. In this vat, the immediate principles with base of carbon and hydrogen, such as the extracts of madder and bran, perform the disoxydizing function of the copperas in the cold vat. The pastel vats require most skill and experience, in consequence of their complexity. The greatest difficulty occurs in keeping them in a good condition, because they vary progressively as the dyeing goes on, by the abstraction of the indigotine, and the modification of the fermentable matter employed to disoxygenate the indigo. The alkaline matter also changes by the action of the air. By the successive additions of indigo, alkali, &c., this vat becomes very difficult to manage with profit and success. The great affair of the dyer is the proper addition of lime; too much or too little being equally injurious.

Sulphate of indigo or Saxon blue is used also to dye silk and wool. If the wools be ill sorted, it will show their differences by the inequalities of the dye. Wool dyed in this bath put into water saturated with sulphureted hydrogen, becomes soon colorless, owing to the disoxygenation of the indigo. The woollen cloth, when exposed to the air for some time resumes its blue color, but not so intensely as before.

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The properties of hematine explain the mode of using logwood. When stuffs are dyed in the infusion or decoction of this wood, under the influence of a base which acts upon the hematine in the manner of an alkali, a blue dye, bordering upon violet, is obtained. Such is the process for dyeing cotton and wool a logwood blue by means of verdigris, crystallized acetate of copper, and acetate of alumina.

When we dye a stuff yellow, red, or orange, we have always bright tints; with blue, we may have a very dark shade, but somewhat violet; the proper black can be obtained only by using the three colors, blue, red, and yellow, in proper proportions. Hence we can explain how the tints of yellow, red, orange, blue, green, and violet, may be browned, by applying to them one or two colors which along with themselves would produce black; and also we may explain the nature of that variety of blacks and grays which seems to be indefinite. Nutgalls and sulphate of iron, so frequently employed for the black dye, give only a violet or bluish gray. The pyrolignite of iron, which contains a brown empyreumatic matter, gives to stuffs a brown tint, bordering upon greenish yellow in the pale hues, and to chestnut brown in the dark ones. By galling cotton and silk, and giving them a bath of pyrolignite of iron, we may, after some alternations, dye them black. Galls, logwood, and a salt of iron, produce merely a very deep violet blue; but by boiling and exposure to air, the hematate of iron is changed, becoming red brown, and favors the production of black. Galls and salts of copper dye stuffs an olive drab, logwood and salts of copper, a violet blue; hence their combination should produce a black. In using sumach as a substitute for galls, we should take into account the proportion of yellow matter it contains. When the best possible black is wanted upon wool, we must give the stuff a foundation of indigo, then pass it into a bath of logwood, sumach, and proto-sulphate of iron. The sumach may be replaced by one third of its weight of nutgalls.

8. Of dyed stuffs considered in reference to the fastness of their colors, when exposed to water, light, heat, air, oxygen, boiling, and reagents.

Pure water without air has no action upon any properly dyed stuff.

Heat favors the action of certain oxygenized bodies upon the carbonaceous and hydrogenous constituents of the stuff; as is seen with regard to chromic acid, and peroxyde of manganese upon cotton goods. It promotes the solvent action of water, and it even affects some colors. Thus Prussian blue applied to silk, is reduced to peroxyde of iron by long boiling.

Light without contact of air affects very few dyes.

Oxygen, especially in the nascent state, is very powerful upon dyes. See Bleaching.

The atmosphere in a somewhat moist state affects many dyes, at an elevated temperature. Silk dyed pink, with safflower, when heated to 400° F., becomes of a dirty white hue in the course of an hour. The violet of logwood upon alumed wool becomes of a dull brown at the same temperature in the same time. But both stand a heat of 300° F. Brazil red dye, turmeric, and weld yellow dyes, display the same phenomena. These facts show the great fixity of colors commonly deemed tender. The stuffs become affected to a certain degree, under the same circumstances as the dyes. The alterability even of indigo in the air is shown in the wearing of pale blue clothes; in the dark blue cloth there is such a body of color, that it resists proportionally longer; but the seams of coats exhibit the effect very distinctly. In silk window curtains, which have been long exposed to the air and light, the stuff is found to be decomposed, as well as the color.

Boiling was formerly prescribed in France as a test of fast dyes. It consisted in putting a sample of the dyed goods in boiling water, holding in solution a determinate quantity of alum, tartar, soap, and vinegar, &c. Dufay improved that barbarous test. He considered that fast-dyed cloth could be recognised by resisting an exposure of twelve hours to the sunshine of summer, and to the midnight dews; or of sixteen days in winter.

In trying the stability of dyes, we may offer the following rules:—

That every stuff should be exposed to the light and air; if it be intended to be worn abroad, it should be exposed also to the wind and rain; that carpets, moreover, should be subjected to friction and pulling, to prove their tenacity; and that cloths to be washed should be exposed to the action of hot water and soap.

In examining a piece of dyed cotton goods, we may proceed as follows:—

Suppose its color to be orange-brown. We find first that it imparts no color to boiling water; that protochloride of tin takes out its color; that plunged into a solution of ferroprussiate of potash it becomes blue; and that a piece of it being burned, leaves a residuum of peroxyde of iron; we may thence conclude that the dyeing matter is peroxyde of iron.

Suppose we have a blue stuff which may have been dyed either with indigo or with Prussian blue, and we wish to know what it will become in use. We inquire first into the nature of the blue. Hot water slightly alkaline will be colored blue by it, if it has been dyed with sulphate of indigo; it will not be colored if it was dyed in the indigo vat, but it will become yellow by nitric acid. Boiling water, without becoming colored itself, will destroy the Prussian blue dye; an alkaline water will convert its color into an iron rust tint; nitric acid, which makes the indigo dye yellow, makes that of Prussian blue green. The liquor resulting from boiling alkaline water on the Prussian blue cloth, will convert sulphate of iron into Prussian blue.

9. Division. Of dyeing viewed in its relation to chemistry.

The phenomena of dyeing have been ascribed to very different causes; by some they were supposed to depend upon mechanical causes, and by others upon the forces from which chemical effects flow. Hellot, in conformity with the first mode of explanation, thought that the art of dyeing consisted essentially in opening the pores in order to admit coloring matters into them, and to fix them there by cooling, or by means of a mordant imagined to act like a cement.

Dufay in 1737, Bergmann in 1776, Macquer in 1778, and Berthollet in 1790, had recourse to chemical affinities, to explain the fixation of the coloring principles upon stuffs, either without an intermedium, like indigo, walnut peels, annotto; or by the intervention of an acid, a salifiable base, or a salt, which were called mordants. When bodies present phenomena which we refer to an attraction uniting particles of the same nature, whether simple or compound, to form an aggregate, or to an affinity which unites the particles of different natures to form them into a chemical compound, these bodies are in apparent contact. This happens precisely in all the cases of the mutual action of bodies in an operation of dyeing; if their particles were not in apparent contact, there would be absolutely no change in their respective condition. When we see stuffs and metallic oxydes in apparent contact, form a mutual union of greater or less force, we cannot therefore help referring it to affinity. We do not know how many dyes may be fixed upon the same piece of cloth; but in the operations of the dye-house sufficiently complex compounds are formed, since they are always stuffs, composed of three or four elements, which are combined with at least binary acid or basic compounds; with simple salts compounded themselves of two immediate principles at least binary; with double salts composed of two simple salts; and finally with organic dye-stuffs containing three or four elements. We may add that different species belonging to one of these classes, and different species belonging to different classes, may unite simultaneously with one stuff. The union of stuffs with coloring matters appears, in general, not to take place in definite proportions; though there are probably some exceptions.

We may conclude this head by remarking, that, besides the stuff and the coloring matter, it is not necessary, in dyeing, to distinguish a third body, under the name of *mordant;* for the idea of mordant does not rest upon any definite fact; the body to which this name has been given being essentially only one of the immediate principles of the colored combination which we wish to fix upon the stuff.

10. Division. Of dyeing in its relation with caloric, mechanics, hydraulics, pneumatics, and optics.

Dyeing baths, or coppers, are heated directly by a furnace, or by means of steam conducted in a pipe from a boiler at a certain distance from the bath. In the first case, the vessels are almost always made of copper; only, in special cases, for the scarlet and some delicate silk dyes, of tin; in the second case, they are of copper, iron, or wood. A direct fire is more economical than heating steam pipes, where there is only one or two baths to heat, or where the labors are often suspended. Madder and indigo vats, when heated by steam, have it either admitted directly into the liquor, or made to circulate through pipes plunged into it, or between the copper and an exterior iron or wood case. See the end of this article.

Everything else being equal, dyeing with heat presents fewer difficulties towards obtaining an evenly color, than dyeing in the cold; the reason of which may be found in the following facts:—The air adhering to the surface of stuffs, and that interposed between the fibres of their constituent yarns, is more easily extricated in a hot bath than a cold one, and thus allows the dye liquor to penetrate more easily into their interior: in the second place, the currents which take place in a hot bath, and which tend incessantly to render its contents uniform, by renewing continually the strata of liquid in contact with the stuff, contribute mainly to render the dyeing evenly. In cold dyeing, it is necessary to stir up the bath from time to time: and when goods are first put in, they must be carefully dipped, then taken out, pressed, and wrung, several times in succession till they be uniformly moistened.

The mechanical relations are to be found in the apparatus employed for wincing, airing, and pressing the goods, as we have described under Calico Printing and Bandana. The hydraulic relations refer to the wash-wheels and other similar apparatus, of which an account is given under the same articles. The optical relations have been already considered. In the sequel of this article an automatic dyeing vat will be described.

The extracts of solutions of native dye-stuffs may be divided into two classes, in reference to their habitudes with the oxygen of the atmosphere; such as continue essentially unaltered in the air, and such as suffer oxydation, and thereby precipitate a determinate coloring matter. The dyes contained in the watery infusions of the different vegetable and animal substances which do not belong to the second class, are feebly attached to their solvents, and quit them readily for any other bodies that possess an attraction for them. On this principle, a decoction of cochineal, logwood, brazil wood, or a solution of sulphate of indigo, by digestion with powdered bone black, lose their color, in consequence of the coloring particles combining by a kind of capillary attraction with the porous carbon, without undergoing any change. The same thing happens when well-scoured wool is steeped in such colored liquids; and the color which the wool assumes by its attraction for the dye, is, with regard to most of the above colored solutions, but feeble and fugitive, since the dye may be again abstracted by copious washing with simple water, whose attractive force therefore overcomes that of the wool. The aid of a high temperature, indeed, is requisite for the abstraction of the color from the wool and the bone-black, probably by enlarging the size of the pores, and increasing the solvent power of the water.

Those dye-baths, on the contrary, whose coloring matter is of the nature of extractive or apothême, form a faster combination with stuffs. Thus the yellow, fawn, and brown dyes, which contain tannin and extractive, become oxygenated by contact of air, and insoluble in water; by which means they can impart a durable dye. When wool is impregnated with decoctions of that kind, its pores get charged by capillarity, and when the liquid becomes oxygenated, they remain filled with a color now become insoluble in water. A similar change to insolubility ensues when the yellow liquor of the indigo vat gets oxydized in the pores of cotton and wool, into which it had been introduced in a fluid state. The same change occurs when protosulphate of iron is converted into persulphate, with the deposition of an insoluble peroxyde in the substance of the stuff. The change here effected by oxydation can, in other circumstances, be produced by acids which have the power of precipitating the dye-stuff in an insoluble state, as happens with decoction of fustic.

Hence we perceive that the dyeing of fast colors rests upon the principle, that the colors dissolved in the vat, during their union with the stuff, should suffer such a change as to become insoluble in their former menstruum. The more this dye, as altered in its union with the stuff, can resist other menstrua or agents, the faster it will be. This is the essential difference between dyeing and painting; or applying a coat of pigment devoid of any true affinity for the surface.

If we mix a clear infusion of a dye with a small quantity of a solution of an earthy or metallic salt, both in water, the limpid liquids soon become turbid, and there gradually subsides sooner or later, according to the nature of the mixture, a colored precipitate, consisting of the altered dye united with a basic or subsalt. In this compound the coloring matter seems to act the part of an acid, which is saturated by a small quantity of the basis, or in its acid relationship is feeble, so that it can also combine with acids, being in reference to them a base. The decomposition of a salt, as alum, by dyes, is effected principally through the formation of an insoluble subsalt, with which the color combines, while a supersalt remains in the bath, and modifies, by its solvent reaction, the shade of the dyed stuff. Dyed stuffs may be considered as composed of the fibrous body intimately associated with the coloring matter, the oxyde, and acid, all three constituting a compound salt. Many persons have erroneously imagined, that dyed goods contained none of the acid employed in the dye bath; but they forget that even potash added to alum does not throw down the pure earthy basis, but a subsalt; and they should not ascribe to coloring matter a power of decomposition at all approaching to that of an alkali. Salts, containing strong acids, saturate a very large quantity of coloring matter, in proportion to their place in the scale of chemical equivalents. Mere bases, such as pure alumina, and pure oxyde of tin, have no power of precipitating coloring matter; when they seem to do so, they always contain some acid.

Such salts, therefore, as have a tendency to pass readily into the basic state, are peculiarly adapted to act as mordants in dyeing, and to form colored lakes. Magnesia affords as fine a white powder as alumina, and answers equally well to dilute lakes, but its soluble salts cannot be employed to form lakes, because they do not pass into the basic state. This illustration is calculated to throw much light upon dyeing processes in general.

The color of the lake depends very much upon the nature of the acid, and the basis of the precipitating salt. If it be white, like alumina and oxyde of tin, the lake will have, more or less, the color of the dye, but brightened by the reflection of white light from the basis; while the difference of the acid occasions a difference in the hue. The colored bases impart more or less of their color to the lakes, not merely in virtue of their own tints, but of their chemical action upon the dye.

Upon these principles a crimson precipitate is obtained from infusions of cochineal by alum and salt of tin, which becomes scarlet by the addition of tartar; by acetate of lead, a violet blue precipitate is obtained, which is durable in the air; by muriate of lime, a pink brown precipitate falls, which soon becomes black, and at last dirty green; by the solution of a ferruginous salt, the precipitates are dark violet and black; and, in like manner, all other salts with earthy or metallic bases, afford diversities of shade with cochineal. If this dye stuff be dissolved in weak water of ammonia, and be precipitated with acetate of lead, a green lake is obtained, which, after some time, will become green on the surface by contact of air, but violet and blue beneath. Hence it appears, that the shade of color of a lake depends upon the degree of oxydation or change of the color caused by the acid of the precipitating salt, upon the degree of oxydation or color of the oxyde which enters into union with the dye, and upon its quantity in reference to that of the coloring principle.

Such lakes are the difficultly soluble salts which constitute the dyeing materials of stuffs. Their particles, however, for the purposes of dyeing, must exist in a state of extremely fine division in the bath liquor, in order that they may penetrate along with it into the minute pores of textile fibres, and fill the cavities observed by means of the microscope in the filaments of wool, silk, cotton, and flax. I have examined these stuffs with an achromatic microscope, and find that when they are properly dyed with fast colors, the interior of their tubular texture is filled, or lined at least, with coloring matter. When the bath contains the coloring particles, so finely divided that they can pass through filtering paper, it is capable of dyeing; but if the infusion mixed with its mordant be flocculent and ready to subside, it is unfit for the purpose. In the latter case, the ingredients of the dye have already become aggregated into compounds too coherent and too gross for entering into combination with fibrous stuffs. Extractive matter and tannin are particularly liable to a change of this kind, by the prolonged action of heat in the bath. Hence, also, an alkaline solution of a coloring matter affords no useful dye bath, when mixed with the solution of a salt having an earthy or metallic basis.

These circumstances, which are of frequent occurrence in the dye-house, render it necessary always to have the laky matter in a somewhat soluble condition, and to effect its precipitation within the pores of the stuffs, by previously impregnating them with the saline solutions by the aid of heat, which facilitates their introduction.

When a mordant is applied to any stuff, the portion of it remaining upon the surface of the fibres should be removed; since, by its combination with the coloring matter, it would be apt to form an external crust of mere pigment, which would block up the pores, obstruct the entrance of the dye into the interior, and also exhaust to no purpose the dyeing power of the bath. For this reason the stuffs, after the application of the mordant, are drained, squeezed, washed, and sometimes (particularly with cotton and linen, in calico printing) even hard dried in a hot stove.

The saline mordants, moreover, should not in general possess the crystallizing property in any considerable degree, as this opposes their affinity of composition for the cloth. On this account the deliquescent acetates of iron and alumina are more ready to aid the dyeing of cotton than copperas and alum.

Alum is the great mordant employed in wool dyeing. It is frequently dissolved in water, holding tartar equal to one fourth the weight of the alum in solution; by which addition its tendency to crystallize is diminished, and the resulting color is brightened. The alum and tartar combine with the stuff without suffering any change, and are decomposed only by the action of the coloring matters in the dye bath. The alum operates solely in virtue of its sulphuric acid and earthy basis; the sulphate of potash present in that salt being rather injurious. Hence, if a sulphate of alumina free from iron could be readily obtained, it would prove a preferable mordant to alum. It is also probable, for the reasons above assigned, that soda alum, a salt much less apt to crystallize than potash or ammonia alum, would suit the dyer very well. In order to counteract the tendency of common alum to crystallize, and to promote its tendency to pass into a basic salt, one eighth part of its weight of potash is added to its solution, or the equivalent in chalk or soda.

We shall conclude this account of the general principles of dyeing, with Mr. Delaval's observations on the nature of dyes, and a list of the different substances used in dyeing, in reference to the colors produced by them.

Sir Isaac Newton supposed colored matters to reflect the rays of light; some bodies reflecting the more, others the less, refrangible rays most copiously; and this he conceived to be the true, and the only reason of their colors. Mr. Delaval, however, proved, in the 2d vol. of the "Memoirs of the Philosophical and Literary Society of Manchester," that, "in transparent colored substances, the coloring substance does not reflect any

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light; and that when, by intercepting the light which was transmitted, it is hindered from passing through substances, they do not vary from their former color to any other color, but become entirely black;" and he instances a considerable number of colored liquors, none of them endued with reflective powers, which, when seen by transmitted light, appeared severally in their true colors; but all of them, when seen by incident light, appeared black; which is also the case of black cherries, black currants, black berries, &c., the juices of which appeared red when spread on a white ground, or otherwise viewed by transmitted instead of incident light; and he concludes, that bleached linen, &c., "when dyed or painted with vegetable colors, do not differ in their manner of acting on the rays of light, from natural vegetable bodies; both yielding their colors by transmitting through the transparent colored matter the light which is reflected from the white ground:" it being apparent, from different experiments, "that no reflecting power resides in any of their components, except in their white matter only," and that "transparent colored substances, placed in situations by which transmission of light through them is intercepted, exhibit no color, but become entirely black."

The art of dyeing, therefore, (according to Mr. Delaval,) "consists principally in covering white substances, from which light is strongly reflected, with transparent colored media, which, according to their several colors, transmit more or less copiously the rays reflected from the white," since "the transparent media themselves reflect no light; and it is evident that if they yielded their colors by reflecting, instead of transmitting the rays, the whiteness or color of the ground on which they are applied, would not in anywise alter or affect the colors which they exhibit."

But when any opaque basis is interposed, the reflection is doubtless made by it, rather than by the substance of the dyed wool, silk, &c., and more especially when such basis consists of the white earth of alum, or the white oxyde of tin; which, by their strong reflective powers, greatly augment the lustre of colors. There are, moreover, some opaque coloring matters, particularly the acetous, and other solutions of iron, used to stain linen, cotton, &c., which must necessarily themselves reflect, instead of transmitting the light by which their colors are made perceptible.

The compound or mixed colors, are such as result from the combination of two differently colored dye stuffs, or from dyeing stuffs with one color, and then with another. The simple colors of the dyer are red, yellow, blue, and black, with which, when skilfully blended, he can produce every variety of tint. Perhaps the dun or fawn color might be added to the above, as it is directly obtained from a great many vegetable substances.

1. Red with yellow, produces orange; a color which, upon wool, is given usually with the spent scarlet bath. To this shade may be referred flame color, pomegranate, capuchin, prawn, jonquil, *cassis*, chamois, *café au lait*, aurora, marigold, orange peel, *mordorés*, cinnamon, gold, &c. Snuff, chestnut, musk, and other shades are produced by substituting walnut peels or sumach for bright yellow. If a little blue be added to orange, an olive is obtained. The only direct orange dyes are annotto, and subchromate of lead; see Silk and Wool Dyeing.

2. Red with blue produces purple, violet, lilach, pigeon's neck, mallow, peach-blossom, *bleu de roi*, lint-blossom, amaranth.

3. Red with black; brown, chocolate, marone, &c.

4. Yellow with blue; green of a great variety of shades, such as nascent green, gay green, grass green, spring green, laurel green, sea green, celadon green, parrot green, cabbage green, apple green, duck green.

5. Mixtures of colors, three and three, and four and four, produce an indefinite diversity of tints; thus red, yellow, and blue, form brown olives, and greenish grays; in which the blue dye ought always to be first given, lest the indigo vat should be soiled by other colors. Red, yellow, and gray, (which is a gradation of black,) give the dead-leaf tint, as well as dark orange, snuff color, &c. Red, blue, and gray, give a vast variety of shades; as lead gray, slate gray, wood-pigeon gray, and other colors, too numerous to specify. See Brown Dye.

The following list of dyes, and the coloring substances which produce them, may prove useful.

Red. Cochineal, kermes, lac, madder, archil, carthamus or safflower, brazil wood logwood, periodide of mercury, alkanet.

Yellow. Quercitron. weld, fustic, (yellow wood,) annotto, sawwort, dyer's broom, turmeric, fustet, (*rhus cotinus*,) Persian and Avignon berries, (*rhamnus infectorius*,) willow, peroxyde of iron chromate of lead, (chrome yellow,) sulphuret of arsenic, hydrosulphuret of antimony; nitric acid on silk.

Blue. Indigo, woad or pastel, Prussian blue, turnsole or litmus, logwood with a salt of copper.

Black. Galls, sumach, logwood, walnut peels, and other vegetables which contain tannin and gallic acid, along with ferruginous mordants. The anacardium of India.

Green. These are produced by the blue and yellow dyes skilfully combined; with the exception of the chrome green, and perhaps the copper green of Schweinfurt.

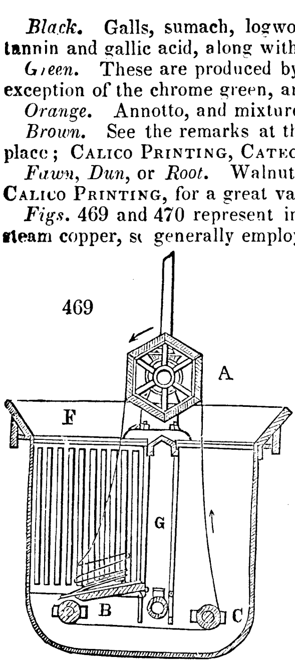
Orange. Annotto, and mixtures of red and yellow dyes; subchromate of lead.

Brown. See the remarks at the beginning of this article; BROWN in its alphabetical place; CALICO PRINTING, CATECHU, and MANGANESE.

Fawn, *Dun*, or *Root.* Walnut peels, sumach, birch-tree, henna, sandal wood. See CALICO PRINTING, for a great variety of these dyes.

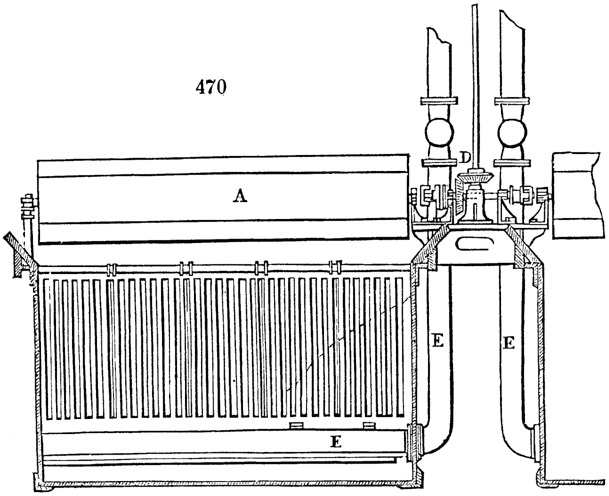
Figs. 469 and 470 represent in a cross and longitudinal section the automatic dyeing steam copper, so generally employed in the well-appointed factories of Lancashire.

469



A is the long reel, composed at each end of six radial iron arms or spokes, bound at their outer extremities with a six sided wooden frame; these two terminal hexagons are connected by long wooden laths, seen above and below A in *fig.* 470. F shows the sloping border or ledge of the copper. B and C are rollers laid horizontally, for facilitating the continuous motion of the series of pieces of goods stitched together into an endless web, which are made to travel by the incessant rotations of the reel. Immediately above the roller B in *fig.* 469, all the spare foldings of the web are seen resting upon the sloping wooden grating, which guides them onwards in the direction indicated by the arrow. The dye stuffs are put within the middle grating, like a hen-coop, marked G. Each copper is 6 feet long, 3½ feet wide, 3½ feet deep, exclusive of the top ledge, 9 inches high. Such steam coppers are usually erected in pairs, and moved by a common horizontal bevel wheel seen at D in *fig.* 470, fixed upon a vertical shaft, shifted into gear by a wheel at its top, with one of the driving shafts of the factory. Upon each side of D, the two steam pipes for supplying the right and left hand coppers are seen; each provided with a stop cock for admitting, regulating, or cutting off the steam. These steam pipes descend at E E, the horizontal branch having several orifices in its upper surface. The horizontal shaft in a line with the axes of the reels, and which turns them, is furnished upon each side with a clutch for putting either of the reels into or out of gear, that is to say, setting it a going, or at rest, in a moment by the touch of a forked lever.

470



The steam pipe of distribution E lies horizontally near the bottom of the middle coop, as shown under G in *fig.* 469, and sends up the steam through its numerous orifices, among the dye-stuffs and water by which it is covered. Thus the infusion or decoction is continually advancing in the copper, during the incessant locomotion of the endless web. The horizontal pipe traverses the copper from end to end, and is not stopped short in the middle. Each of these coppers can receive two, three, or more parallel pieces of goods at a time, the reel and copper being divided into so many compartments by transverse wooden spars.

E.

EARTHS. (*Terres*, Fr.; *Erden*, Germ.) Modern science has demonstrated that the substances called primitive earths, and which prior to the great electro-chemical career of Sir H. Davy, were deemed to be elementary matter, are all compounds of certain metallic bases and oxygen, with the exception of silica, whose base, silicon, being analogous to boron, has led that compound to be regarded as an acid; a title characteristic of the part it extensively performs in neutralizing alkaline bodies, in mineral nature, and in the processes of art. Four of the earths, when pure, possess decided alkaline properties, being more or less soluble in water, having (at least 3 of them) an acrid alkaline taste, changing the purple infusion of red cabbage to green, most readily saturating the acids, and affording thereby neutro-saline crystals. These four are *baryta*, *strontia*, *lime* (*calcia*), *magnesia*. The earths proper are five in number; *alumina*, *glucina*, *yttria*, *zirconia*, and *thorina*. These do not change the color of infusion of cabbage or tincture of litmus, do not readily neutralize acidity, and are quite insoluble in water. The alkalis are soluble in water, even when carbonated; a property which distinguishes them from the alkaline earths. *Lithia* must for this reason be considered to be an alkali. See the above substances in their alphabetical places.

EAU DE COLOGNE. This well-known perfume is a solution of different volatile oils in pure strong spirit. The principal condition for the preparation of a fine water, is the employment of a spirit quite devoid of fusel-oil (oil of grain), and of all foreign odor.

In respect to the proportion and kind of oils employed, we have numerous formulæ. It is of importance that these oils, which are usually purchased of the druggists of the south of France, should be of the finest quality, and that no oil should be used in sufficient quantity to allow of its peculiar odor being recognisable in the mixture. The oils are to be dissolved in spirit, and the mixture allowed to stand for some weeks (or still better for some months) to improve its odor. Distillation does not effect this; on the contrary a fresh distilled water requires to be kept a much longer time. Distillation is indeed objectionable, for on account of the great volatility of the spirit, the oils in part remain behind in the still. Distillation can improve the odor only when the less volatile oil has been used in too great a quantity, and we wish to obtain a better proportion. Before all things, we should employ a pure, old, strong spirit, and not too much of, nor a too strongly smelling oil.

The different sorts of volatile oil which are obtained from varieties of citrons, oranges, and lemons, in different states of maturity, are the most important; and, therefore, it is most important to ascertain their purity and goodness.

Forster gives the following formula for the preparation of a fine eau de Cologne: Take of rectified spirit 82 per cent. of Tralles (=sp. gr. 0·855), 6 (wine) quarts; essence of oranges, essence of bergamot, essence of citron, essence of limette, and essence of petits grains, of each, ℥j; essence of cedro, essence of cedrat, essence de Portugal, and essence de neroli, of each ℥ss; oil of rosemary, ʒij; and oil of thyme, ʒj.

Otto gives the following formula for a good eau de Cologne: Rectified spirit of 86 per cent. of Tralles (=0·846 sp. gr.), 200 (wine) quarts; oil of citrons, lb. iv; oil of bergamot, lb. ij; oil of neroli, ⅝lb.; oil of lavender, lb. ss; oil of rosemary, ¼ lb.; and spirit of ammonia, ℥ss. Mix. Don't distil.

This preparation has long possessed great celebrity, in consequence chiefly of the numerous virtues ascribed to it by its venders; and is resorted to by many votaries of fashion as a panacea against ailments of every kind. It is, however, nothing more than aromatized alcohol, and as such, an agreeable companion of the toilet. Numerous fictitious recipes have been offered for preparing *eau de Cologne;* the following may be reckoned authentic, having been imparted by Farina himself to a friend.

Take 60 gallons of silent brandy; sage, and thyme, each 6 drachms; balm-mint and spearmint, each 12 ounces; calamus aromaticus, 4 drachms; root of angelica, 2 drachms camphor, 1 drachm; petals of roses and violets, each 4 ounces; flowers of lavender, 2 ounces; flowers of orange, 4 drachms; wormwood, 1 ounce; nutmegs, cloves, cassia, lignea, mace, each 4 drachms. Two oranges and two lemons, cut in pieces. Allow the whole to macerate in the spirit during 24 hours, then distil off 40 gallons by the heat of a water bath. Add to the product:

Essence of lemons, of cedrat, of balm-mint, of lavender, each 1 ounce 4 drachms;

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neroli and essence of the seed of anthos, each 4 drachms; essence of jasmin, 1 ounce; of bergamot, 12 ounces. Filter and preserve for use.

Cadet de Gassincourt has proposed to prepare *eau de Cologne* by the following recipe: Take alcohol at 32° B., 2 quarts; neroli, essence of cedrat, of orange, of lemon, of bergamot, of rosemary, each 24 drops; add 2 drachms of the seeds of lesser cardamoms, distil by the heat of a water bath a pint and a half. When prepared as thus by simple mixture of essences without distillation, it is never so good.

EAU DE LUCE, is a compound formed of the distilled oil of amber and water of ammonia.

EBULLITION. (Eng. and Fr.; *Kochen*, Germ.) When the bottom of an open vessel containing water is exposed to heat, the lowest stratum of fluid immediately expands, becomes therefore specifically lighter, and is forced upward by the superior gravity of the superincumbent colder and heavier particles. The heat is in this way diffused through the whole liquid mass, not by simple communication of that power from particle to particle as in solids, called the *conduction* of caloric, but by a translation of the several particles from the bottom to the top, and the top to the bottom, in alternate succession. This is denominated the *carrying* power of fluids, being common to both liquid and gaseous bodies. These internal movements may be rendered very conspicuous and instructive, by mingling a little powdered amber with water, contained in a tall glass cylinder, standing upon a sand-bath. A column of the heated and lighter particles will be seen ascending near the axis of the cylinder, surrounded by a hollow column of the cooler ones descending near the sides. That this molecular translation or locomotion is almost the sole mode in which fluids get heated, may be demonstrated by placing the middle of a pretty long glass tube, nearly filled with water, obliquely over an argand flame. The upper half of the liquid will soon boil, but the portion under the middle will continue cool, so that a lump of ice may remain for a considerable time at the bottom. When the heat is rapidly applied, the liquid is thrown into agitation, in consequence of elastic vapor being suddenly generated at the bottom of the vessel, and being as suddenly condensed at a little distance above it by the surrounding cold columns. These alternate expansions and contractions of volume become more manifest as the liquid becomes hotter, and constitute the *simmering* vibratory sound which is the prelude of ebullition. The whole mass being now heated to a pitch compatible with its permanent elasticity, becomes turbulent and explosive under the continued influence of fire, and emitting more or less copious volumes of vapor, is said to boil. The further elevation of temperature, by the influence of caloric, becomes impossible in these circumstances with almost all liquids, because the vapor carries off from them as much heat in a latent state as they are capable of receiving from the fire.

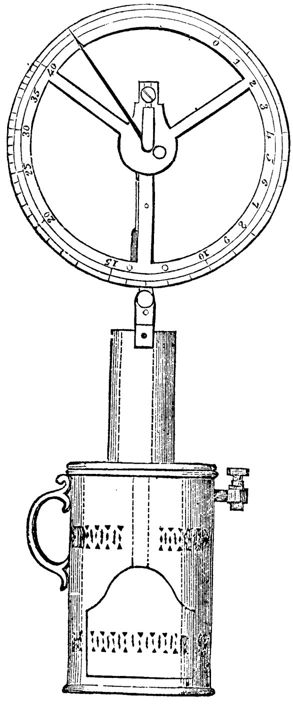
The temperature at which liquids boil in the open air varies with the degree of atmospheric pressure, being higher as that is increased, and lower as it is diminished. Hence boiling water is colder by some degrees in bad weather, or in an elevated situation, with a depressed barometer, than in fine weather, or at the bottom of a coal-pit, when the barometer is elevated. A high column of liquid, also, by resisting the discharge of the steam, raises the boiling point. In *vacuo*, all liquids boil at a temperature about 124° F. lower than under the average atmospheric pressure. For a table of elasticities, see VAPOR. Gay Lussac has shown that liquids are converted into vapors more readily, or with less turbulence, when they are in contact with angular or irregular, than with smooth surfaces; that they therefore boil at a heat 2° F. lower in metallic than in glass vessels, probably owing to the greater polish of the latter. For example, if into water about to boil in a glass matrass, iron filings, ground glass, or any other insoluble powder be thrown, such a brisk ebullition will be instantly determined as will sometimes throw the water out of the vessel; the temperature at the same time sinking two degrees F. It would thence appear that the power of caloric, like that of electricity, becomes concentrated by points.

The following table exhibits the boiling heats, by Fahrenheit's scale, of the most important liquids:—

Ether, specific gravity 0·7365 at 48°		100°
Carburet of sulphur		113
Alcohol, sp. grav. 0·813	Ure	173·5
Nitric acid, 1·500	Dalton	210
Water		212
Saturated solution of Glauber salt	Biot	213⅓
do. do. Acetate of lead	do.	215⅔
do. do. Sea salt	do.	224⅓
do. do. Muriate of lime,	Ure	285
do. do. do. 1 + water 2,	do.	230
do. do. do. 35·5 + do. 64·5,	do.	235

Saturated solution of Muriate of lime 40·5+water 59·5		Ure,	240
Muriatic acid, sp. grav.	1·094	Dalton,	232
do. do.	1·127	do.	222
Nitric acid, do.	1·420	do.	248
do. do.	1·30	do.	236
Rectified petroleum		Ure,	306
Oil of turpentine		do.	316
Sulphuric acid, sp. grav.	1·848	Dalton,	600
do. do.	1·810	do.	473
do. do.	1·780	do.	435
do. do.	1·700	do.	374
do. do.	1·650	do.	350
do. do.	1·520	do.	290
do. do.	1·408	do.	260
do. do,	1·300	do.	240
Phosphorus		do.	554
Sulphur		do.	570
Linseed oil		do.	640
Mercury		Dulong,	662
do.		Crighton,	656
Saturated solution of Acetate soda, containing	60 per cent.	Griffiths,	256
do. Nitrate of soda,	60	do.	246
do. Rochelle salt,	90	do.	240
do. Nitre,	74	do.	238
do. Muriate of ammonia,	50	do.	236
do. Tartrate of potash,	68	do.	234
do. Muriate of soda,	30	do.	224
do. Sulphate of magnesia,	57·5	do.	222
do. Borax,	52·5	do.	222
do. Phosphate of soda,	?	do.	222
do. Carbonate of soda,	?	do.	220
do. Alum,	52	do.	220
do. Chlorate of potash,	40	do.	218
do. Sulphate of copper,	45	do.	216

471



Ebullition Alcoholmeter. That the boiling temperature of water is increased by holding neutro-saline and saccharine substances in solution has been long known, and has been the subject of many experiments, made partly with the view of ascertaining from that temperature the proportion of the salt or sugar, and partly with the view of obtaining a practical liquid bath. But it seems to have been reserved for the Abbé Brossard-Vidal, of Toulon, to have discovered that the boiling temperature of alcoholic liquors is, in most cases, proportional to the quantity of alcohol, irrespectively of the quantity of neutro-saline or saccharine matter dissolved in them. When, however, such a quantity of dry carbonate of potash, or sugar, is added to a spirituous liquor as to abstract or fix in the solid state a portion of the water present, then the boiling temperature of that mixture will be lowered in proportion to the concentration of the alcohol, instead of being raised, as would be the case with water so mixed. But, generally speaking, it may be assumed as a fact, that the boiling point of an alcoholic liquor is not altered by a moderate addition of saline, saccharine, or extractive matter. On this principle, M. Brossard-Vidal constructed the instrument represented in *fig.* 471, for determining by that temperature the proportion of alcohol present. His chief object was to furnish the revenue boards of France with a means of estimating directly the proportion of alcohol in wines, so as to detect the too common practice of introducing brandy into their cities and towns under the mask of wine, and thereby committing a fraud upon the *octroi;* as the duty on spirits is much higher than on wines.

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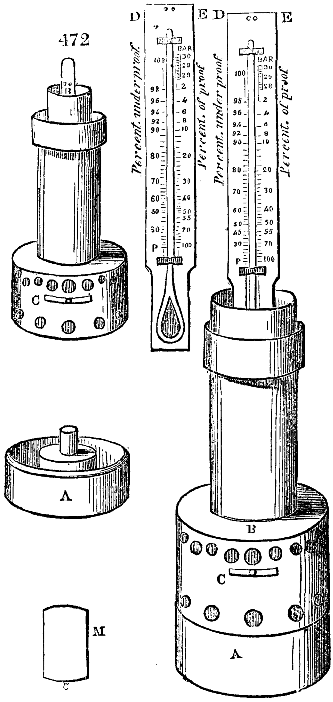
The above instrument consists of a spirit-lamp, surmounted by a small boiler, into which a large cylindric glass bulb is plunged, having an upright stem of such calibre, that the quicksilver contained in them may, by its expansion and ascent when heated, raise before it a little glass float in the stem, which is connected by a thread with a similar glass bead, that hangs in the air. The thread passes round a pulley, which turning with the motion of the beads causes the index to move along the graduated circular scale. The numbers on this scale represent per centages of absolute alcohol, so that the number opposite to which the index stops, when the liquor in the cylinder over the lamp boils briskly, denotes the per centage of alcohol in it.

472



That instrument was placed in my hands three years ago by Mr. Field, who had obtained a patent in this country for determining thereby the strength of spirituous liquors. I have made a great many experiments on the boiling points of alcohol at various successive degrees of watery dilution, and verified the general utility of the contrivance; but I found the construction of the instrument subject to general defects. The mass of mercury to be heated in the large bulb was so great as to occasion some loss of alcohol in the course of the experiment; the length of the thread was liable to be affected by the moisture of the air; it occasionally failed to move the pulley with sufficient delicacy on account of friction, and when the spirit in the lamp got heated in its case, it flared up and burned the thread, thus rendering the apparatus useless till a fresh thread was experimentally adjusted to the beads.

On these accounts I renounced the construction of M. Vidal, and adopted the more simple and direct form of indication represented in *fig.* 472.

It consists, 1, of a flat spirit-lamp A, surrounded by a saucer for containing cold water to keep the lamp cool, should many experiments require to be made in succession; 2, of the boiler B, which fits by its bottom cage C, upon the case of the lamp. At the point C, is seen the edge of the damper-plate for modifying the flame of the lamp, or extinguishing it when the experiment is completed. D is the thermometer, made with a very minute bore, in the manner of the Rev. Mr. Wollaston's instrument for measuring the height of a mountain by the boiling point of water on its summit. The bottom of the scale in the ebullition thermometer, is marked P for proof on the left side, and 100 (of proof spirit) on the right side. It corresponds to 178·6 Fahr. very nearly, or the boiling point of alcohol of 0·920 specific gravity. The following table gives the boiling points corresponding to the indicated densities:—

Temp. Fahr.	Specific gravity.	
178·6	0·9200	P.
179·75	0·9321	10 U. P.
180·4	0·9420	20 „
181·00	0.9516	30 „
183·40	0·960	40 „
185·6	0·9665	50 U. P.
189·0	0·9729	60 „
191·80	0·9786	70 „
196·4	0·9850	80 „
202·0	0·992	90 „

The above table is the mean of a great many experiments. When alcohol is stronger than 0·92, or the excise proof, its boiling point varies too little with its progressive increase of strength, to render that test applicable in practice. In fact, even for proof spirits, or spirits approaching in strength to proof, a more exact indication may be obtained by diluting them with their own bulk of water, before ascertaining their strength, and then doubling it.

The boiling point of any alcoholic liquor is apt to rise if the heat be long-continued, and thereby to lead into error in using this instrument. This source of fallacy may be in a great measure avoided by adding to the liquor in the little boiler about a teaspoonful (thirty-five grains) of common culinary salt, which has the curious effect of arresting the mercury in the thermometer at the true boiling point of the spirit, wine,

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or beer, to enable a correct reading to be had. The small measure marked M, holds the requisite quantity of salt.

The thermometer is at first adjusted to an atmospheric pressure of 29·5 inches. When that pressure is higher or lower, both water and alcohol boil at a somewhat higher or lower temperature. In order to correct the error which would hence arise in the indications of this instrument under different states of the weather, a barometrical equation is attached by means of the subsidiary scale E, to the thermometer D.

Having stated the principles and the construction of the ebullition alcoholmeter, I shall now describe the mode of its application.

First.—Light the spirit lamp A.

Second.—charge the boiling vessel B, with the liquid to be tested (to within an inch of the top), introducing at the same time a paper of the powder; then place the vessel B (the damper plate being withdrawn) on to the lamp A.

Third.—Fix the thermometer D on the stem attached to B, with its bulb immersed in the liquid. The process will then be in operation.

The barometrical scale indicated on the thermometer is opposite the mean boiling point of water. Prior to commencing operations for the day, charge the boiler B with water only, and fix the instrument as directed; when the water boils freely, the mercury will become stationary in the stem of the thermometer, opposite to the true barometrical indication at the time. Should the mercury stand at the line 29·5, this will be the height of the barometer, and no correction will be required; but should it stand at any other line, above or below, then the various boiling points will bear reference to that boiling point.

In testing spirituous or fermented liquors of any kind, when the mercury begins to rise out of the bulb of the thermometer into the stem, push the damper-plate half-way in its groove to moderate the heat of the flame. When the liquor boils freely, the mercury will become stationary in the stem; and opposite to its indication, on the left, the under-proof per-centage of spirit may be read off at once, if the barometer stand that day at 29·5 inches; while on the right hand scale, the per centage of proof spirit is shown; being the difference of the former number from 100. The damper-plate is to be immediately pushed home to extinguish the flame.

The alcoholmeter will by itself only indicate the per centage of alcohol contained in any wine, but by the aid of the hydrometer, the proportionate quantity of saccharum in all wines may be readily and easily determined. The hydrometer will show the specific gravity of the liquid upon reference to table No. 1, annexed. In testing a sample of wine, first take the specific gravity, and suppose it to be 989, then charge the boiler of the alcoholmeter with the wine, as directed, and at the boiling point it indicates the presence of alcohol at 69·6 per cent.^{up} whose specific gravity will be found to be 979; deduct that gravity from the gravity of the bulk, or 989, and 10 will remain, which 10 degrees of gravity, upon reference to the wine table, will be found to represent 25 lbs. of saccharine or attractive matter in every 100 gallons, combined with 30$\frac{4}{10}$th gallons of proof spirit.

Sike's hydrometer will only show the sp. gr. of liquids lighter than water (or 1000), and for wines in general use, the gravities being lighter than that article, will answer every purpose; but there are wines whose gravities are heavier than water, such as mountain, tent, rich Malagas, lachrymæ Christi, &c., to embrace which additional weights to the hydrometer will be required, as for cordialized spirits, &c. In testing a sample of rich mountain, its sp. gr. was found to be 1039, or 39 degrees heavier than water, that wine at the boiling point indicated the alcohol 72·5 per cent. ^{up}; but 980 sp. gr. deducted from 1039 leaves 59 degrees of sp. gr.; against 59 of the wine tables will be found 147–5 or 147½ lbs. of saccharine or extractive matter, combined with 27½ gallons of proof spirit to every 100 gallons.

Should the barometer for the day show any other indication above or below the standard of 29·5, the thermometer scale will then only show the apparent strength, and reference must be had to the small ivory indicator, F, it being the counterpart of the barometrical scale of the thermometer; thus should the barometer indicate 30, place 30 of the indicator against the boiling point of the liquid, and opposite the line of 29·5 will be found the true strength.

Example 1. Barometer at 30.—Suppose the mercury to stop at the boiling-point 72·^{up}, place 30 of the indicator against 72 on the thermometer, and the line of 29·5 will cut 69·6·^{up}, the true strength.

Example 2. Barometer at 29.—Suppose the mercury to stop at the same point, 72 ^{up}, place 29 of the indicator against 72 on the thermometer, and the line 29·5 will cut 74-3·^{up}, the true strength.

For malted Liquors.—To all brewers and dealers in fermented liquors, the principle by its application, will supply a great desideratum, as it will not only show the alcohol created in the wort by the attenuation, as well as the original weight of the wort prior

No. I.

TABLE OF SPECIFIC GRAVITIES, by Sikes's Hydrometer, adapted to Field's Patent Alcoholmeter for Cordialized Spirits.

TEMPERATURE 60°. SPECIFIC GRAVITY OF WATER 1000°.

60		70		80		90		100		110		120		130		140		150		160		170		180	
Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.
60	922	70	942	80	961	90	981	100	1000	110	1020	120	1041	130	1063	140	1085	150	1107	160	1129	170	1152	180	1175
1	924	1	943	1	963	1	983	1	1002	1	1022	1	1044	1	1065	1	1087	1	1109	1	1131	1	1155	1	1178
2	926	2	945	2	965	2	985	2	1004	2	1024	2	1046	2	1067	2	1089	2	1111	2	1134	2	1157	2	1180
3	928	3	947	3	967	3	987	3	1006	3	1026	3	1048	3	1069	3	1091	3	1113	3	1136	3	1159	3	1182
4	930	4	949	4	969	4	989	4	1008	4	1029	4	1050	4	1071	4	1093	4	1116	4	1139	4	1162	4	1185
5	932	5	951	5	971	5	991	5	1010	5	1031	5	1052	5	1074	5	1096	5	1118	5	1141	5	1164	5	1187
6	934	6	953	6	973	6	993	6	1012	6	1033	6	1054	6	1076	6	1098	6	1120	6	1143	6	1166	6	1189
7	936	7	955	7	975	7	995	7	1014	7	1035	7	1056	7	1078	7	1100	7	1123	7	1145	7	1168	7	1191
8	938	8	957	8	977	8	997	8	1016	8	1037	8	1058	8	1080	8	1102	8	1125	8	1148	8	1171	8	1194
9	940	9	959	9	979	9	999	9	1018	9	1039	9	1061	9	1082	9	1104	9	1127	9	1150	9	1173	9	1196
10	942	10	961	10	981	10	1000	10	1020	10	1041	10	1063	10	1085	10	1107	10	1129	10	1152	10	1175	10	1199

The foregoing Table, which shows the Specific Gravity on the bulk of the mixture, bears reference to the Table (No 2) of the Alcoholmeter following.

No. 2.

TABLE, showing the lbs. of Sugar per Gallon in Cordialized Spirits, with Per-Centages to be added to the indicated Strength, per the Alcoholmeter.

Difference of Gravity. Llbs. of Sugar per Gallon.		10	15	20	25	30	35	40	45	50	Difference of Gravity. Llbs. of Sugar per Gallon.	
		4 oz. or 25 to 100.	6 oz. 37⅛ to 100	8 oz. 50 to 100.	10 oz. 62½ to 100.	12 oz. 75 to 100.	14 oz. 87½ to 100.	1·0	oz. 1·2	oz. 1·4		
Sp. Grav. of Spirit	Per Cent. of Spirit.										Per Cent. of Spirit.	Sp. Grav. of Spirit.
920	Pf.	1·6	2·5	3·4	4·4	5·3	6·2	7·1	8·1	9·0	Pf.	920
923	2·5	1·6	2·5	3·3	4·3	5·2	6·1	6·9	7·8	8·8	2·5	923
926	5·	1·5	2·4	3·2	4·2	5·0	5·9	6·8	7·7	8·6	5·	926
929	7·5	1·5	2·3	3·2	4·1	4·9	5·8	6·6	7·5	8·4	7·5	929
932	10·	1·4	2·2	3·1	4·0	4·8	5·7	6·5	7·4	8·2	10·	932
935	12·5	1·4	2·2	3·1	3·9	4·7	5·5	6·3	7·2	8·0	12·5	935
938	15·	1·4	2·1	3·0	3·8	4·6	5·4	6·2	7·0	7·8	15·	938
940	17·5	1·3	2·1	2·9	3·7	4·5	5·3	6·0	6·8	7·6	17·5	940
943	20·	1·3	2·0	2·8	3·6	4·4	5·2	5·9	6·7	7·5	20·	943
945	22·5	1·3	2·0	2·7	3·5	4·3	5·0	5·7	6·5	7·3	22·5	945
948	25·	1·2	1·9	2·6	3·4	4·1	4·8	5·5	6·3	7·0	25·	948
950	27·5	1·2	1·9	2·5	3·3	4·0	4·7	5·3	6·1	6·8	27·5	950
952	30·	1·1	1·8	2·4	3·1	3·8	4·5	5·1	5·8	6·5	30·	952
954	32·5	1·1	1·7	2·3	3·0	3·6	4·3	4·8	5·5	6·2	32·5	954
956	35·	1·0	1·6	2·2	2·9	3·5	4·1	4·6	5·3	6·0	35·	956
958	37·5	1·0	1·6	2·1	2·8	3·4	3·9	4·4	5·1	5·8	37·5	958
960	40·	·9	1·5	2·0	2·7	3·2	3·8	4·3	4·9	5·5	40·	960
962	42·5	·9	1·5	2·0	2·6	3·1	3·6	4·1	4·7	5·3	42·5	962
964	45·	·9	1·4	1·9	2·5	3·0	3·5	4·0	4·6	5·1	45·	964
965	47·5	·8	1·4	1·9	2·4	2·9	3·4	3·9	4·4	4·9	47·5	965
967	50·	·8	1·3	1·8	2·3	2·8	3·3	3·8	4·3	4·8	50·	967
969	52·5	·7	1·2	1·7	2·2	2·6	3·1	3·6	4·1	4·5	52·5	969
970	55·	·7	1·2	1·6	2·0	2·4	2·9	3·4	3·8	4·2	55·	970
972	57·5	·6	1·1	1·5	1·9	2·2	2·7	3·1	3·5	3·9	57·5	972
973	60·	·6	1·0	1·4	1·8	2·1	2·5	2·9	3·3	3·6	60·	973
974	62·5	·6	1·0	1·3	1·7	2·0	2·4	2·7	3·1	3·4	62·5	974
976	65·	·5	·9	1·2	1·5	1·8	2·2	2·5	2·8	3·1	65·	976
977	67·5	·5	·8	1·1	1·4	1·7	2·0	2·3	2·6	2·9	67·5	977
979	70·	·4	·7	1·0	1·3	1·5	1·8	2·1	2·4	2·6	70·	979
980	72·5	·4	·7	·9	1·1	1·3	1·6	1·9	2·1	2·3	72·5	980
982	75·	·3	·6	·8	1·0	1·2	1·4	1·6	1·8	2·0	75·	982
983	77·5	·3	·5	·7	·9	1·0	1·2	1·4	1·6	1·8	77·5	983
984	80·	·2	·4	·6	·8	·9	1·0	1·2	1·4	1·6	80·	984
986	82·5	·2	·3	·5	·7	·8	·9	1·0	1·2	1·4	82·5	986
988	85·	·2	·2	·4	·6	·7	·8	·9	1·0	1·2	85·	988
990	87·5	·1	·2	·3	·5	·6	·7	·8	·9	1·0	87·5	990
992	90·	·1	·1	·2	·4	·5	·6	·7	·8	·9	90·	992
994	92·5	- -	·1	·2	·3	·4	·5	·6	·7	·8	92·5	994
996	95·	- -	- -	·1	·2	·3	·4	·5	·6	·7	95·	996
998	97·5	- -	- -	- -	·1	·2	·3	·4	·5	·6	97·5	998

to fermentation, but it will indicate the value of malt liquors in relation to their component parts. It will likewise be a ready means of testing the relative value of worts from sugar compared with grain, as well as being a guide to the condition of stock beers and ales.

To ascertain the strength of malt liquors and their respective values, the instrument has been supplied with a glass saccharometer, testing-glass, and slide-rule. Commence by charging the testing-glass with the liquid, then insert the saccharometer, to ascertain its present gravity or density per barrel, and at whatever number it floats, that will indicate the number of pounds per barrel heavier than water.

Example 1.—Suppose the saccharometer to float at the figure 8, that would indicate 8 lbs. per barrel; then submit the liquid to the boling test, with the salt as before directed, and suppose it should show (the barometrical differences being accounted for) 90-up, that would be equivalent to 10 per cent. of proof alcohol. Refer to the slide-rule, and place A on the slide against 10 on the upper line of figures, and facing B on the lower line will be 18, thus showing that 18 lbs. per barrel have been decomposed to constitute that per centage of spirit; then, by adding the 18 lbs. to the present 8 lbs. per barrel, the result will be 26 lbs., the original weight of the wort after leaving the copper.

Example 2.—The saccharometer marks 10 lbs. per barrel, and at the boiling point it indicates 88-up, equivalent to 12 gallons of proof spirit per cent.; place A against 12, and opposite B will be 21½ lbs. per barrel, when, by adding that to the 10 lbs. present, 31½ lbs. will be the result.

To ascertain the relative Value.—Suppose the price of the 26 lbs. beer to be 36*s.* per barrel, and the 31½ lbs. beer to be 40*s.* per barrel, to ascertain which beer will be the cheapest, place 26 on the opposite side of the rule against 36, and opposite 31½ lbs. will be 43*s.* 7*d.*, showing that the latter beer is the cheapest by 3*s.* 7*d.* per barrel.

By taking an account of the malt liquors by this instrument prior to stocking, it may be ascertained at any time whether any alteration has taken place in their condition, either by an increase of spirit by after fermentation and consequent loss of saccharum, or whether by an apparent loss of both, acetous fermentation has been going on towards the ultimate loss of the whole.

This instrument will likewise truly indicate the quantity of spirit per cent. created in distillers' worts, whether in process of fermentation or ready for the still, the only difference will be in the allowances on the slide-rule.

N.B.—The saccharometers applicable to the foregoing rules for beers, ales, &c., have been adjusted at the temperature 60° Fahrenheit, and will be found correct for general purposes; but where extreme minuteness is required, the variation of temperature must be taken into account, therefore for every 10 degrees of temperature above 60, $\frac{3}{10}$ths of a pound must be added to the gross amount found by the slide-rule; on the contrary, for every 10 degrees below 60, $\frac{3}{10}$ths of a pound must be deducted.

For cordialized Spirits.—The operation in this instance is somewhat different from that of beers which have the alcohol created in the original worts; whereas, in cordialized spirits, gins, &c., the alcohol is the original, and the saccharine matter, or sugar, is an addendum.

If 100 gallons of spirit are required at a given strength, say 50 per cent. under proof, 50 gallons of proof spirit, with the addition of 50 gallons of water, would effect that object, and upon testing it by the alcoholmeter, it would be found as correct as by the hydrometer. But in cordializing spirit it is different, for to the 50 gallons of proof spirit, 50 gallons of sugar and water would be added, thereby rendering the hydrometer useless, except for taking the specific gravity of the bulk, and, according to the quantity of sugar present, so a relative quantity of water must have been displaced; and as the sugar has no reducing properties, the alcoholmeter will only show the strength of the cordial in relation to the water contained in it, as the principle indicates, irrespectively of saccharine or extractive matter present.

Suppose, in making 100 gallons of cordial at 50-up, 3 lbs. of sugar are put to the gallon, or 300 lbs. to the 100 gallons, that 300 lbs., displacing 18$\frac{67}{100}$th gallons of water only 31$\frac{33}{100}$th gallons of water instead of 50 have been applied; the sugar, without reducing properties, making up the bulk of 100 gallons, which is meant to represent 50 per cent. up.

The alcoholmeter will only show at the full point of ebullition the alcoholic strength in relation to the water in the 100 gallons of the mixture, or 35 per cent. -up, leaving 15 per cent. to be accounted for on the bulk.

As the quantity of sugar present must be determined before that per centage can be arrived at, a double object will be effected by so doing, namely, eliciting in all instances the quantity of sugar present, as well as the per centage of spirit to be accounted for.

Example 1.—In taking the sp. gr. of a cordial, suppose it to be found 1076, then submit the liquid to the boiling point, and having ascertained the per centage of alcohol, and it proves to be 35-up, the sp. gr. of alcohol at that strength will be found to be 956; deduct 956 from the sp. gr. of the bulk, or 1076, and 120 will remain; refer that to its amount on the head line of table No. 2, namely, 120, under which will be found 3, representing 3 lbs. of sugar to the gallon; and by running the eye down its column to opposite the alcoholic strength indicated (35 up) will be found 14·9, which represents the per centage of water displaced by the sugar, and which amount of 14·9, added to the 35 per cent. ascertained, makes the total upon the bulk 49·9 per cent.-up, with 3 lbs. of sugar to the gallon.

For Gins, &c.—Example 3. In taking the sp. gr., suppose it to be found 957; then submit to the boiling point, and it proves to be 14-up, whose sp. gr. is 937, which, deducted from 957, leaves sp. gr. 20; on the head-line of table No. 2, under 20, will be found ½, or ½ lb. of sugar to the gallon, and on running the eye down to opposite

14-up, will be found 3·0, which, added to the 14, makes the total on the bulk 17 per cent.-up, with 50 lbs of sugar to the 100 gallons.

To chemists for their tinctures, &c., this instrument will be found essentially useful.

N.B.—Care must be taken that the mercury is entirely in the bulb of the thermometer before it is fixed on the stem for operation, and in all cases (except for water) the salt must be used.

Conclusion.—Wines are peculiarly subject to be mystified by adulterations of various kinds. It will prove of great advantage to the public when the relative quantity of fruit, or *saccharum*, and alcohol requisite to constitute the normal wine of each species is well ascertained.

Some beers possess a remarkable narcotic power, by which they cause drowsiness and stupor without corresponding previous exhilaration. Such beverages may justly be suspected of having been sophisticated with *occulus indicus*, opium, or some analogous drug; and this suspicion may become certainty, if they be shown by the alcoholmeter to contain only a few per cents. of fermented spirit.

The instrument in its complete state is made and sold by Mr. Joseph Long, Little Tower Street. The tables, of which the above is only a portion, and the barometric indicator, have been constructed by him and Mr. Atlee.

EDGE TOOLS. Mr. James Bouydell welds iron and steel together in such a manner that when cut up to form edge tools, the steel will constitute a thin layer to form the cutting edge. He piles a slab or plate of steel upon two or more similar plates of iron, heats in a furnace to a good welding heat, and then passes between grooved or other suitable rollers, to convert it into bars; the steel being in a thin layer either on one of the outer surfaces of the bar, or between two surfaces of iron according to the kind of tool to be made therefrom. The bars thus produced are cut up and manufactured into the shape of the desired articles by forging. If the cutting edge is to extend but a short distance, the steel is applied only near one edge of the pile. In this manner hatchets, adzes, choppers, knives of all kinds, scissors, scythes, chisels, gouges, &c., may be economically manufactured; the steel being used merely for forming the edge, while the requisite stiffness of the tools is obtained by the iron. The compound bars which have the steel on one side are suitable for chisels and other tools, which have a cutting edge on one side, the iron being ground away when making or sharpening the tool. Mr. B. manufactures spades on a somewhat similar plan.—*Newton's Journal*, vol. xxvi. p. 183. See Cutlery and Steel.

EDULCORATE, (*Edulcorer*, Fr.; *Aussüssen*, Germ.) is a word introduced by the alchemists to signify the sweetening, or rather rendering insipid, of acrimonious pulverulent substances, by copious ablutions with water. It means, in modern language, the washing away of all particles soluble in water, by agitation, or trituration with this fluid, and subsequent decantation or filtration.

EFFERVESCENCE. (Eng. and Fr.; *Aufbrausen*, Germ.) When gaseous matter is suddenly extricated with a hissing sound during a chemical mixture, or by the application of a chemical solvent to a solid, the phenomenon, from its resemblance to that of simmering or boiling water, is called effervescence. The most familiar example is afforded in the solution of sodiac powders; in which the carbonic acid gas of sesqui carbonate of soda is extricated by the action of citric or tartaric acid.

EFFLORESCENCE, (Eng. and Fr.; *Verwittern*, Germ.) is the spontaneous conversion of a solid, usually crystalline, into a powder, in consequence either of the abstraction of the combined water by the air, as happens to the crystals of sulphate and carbonate of soda; or by the absorption of oxygen and the formation of a saline compound, as in the case of alum schist, and iron pyrites. Saltpetre appears as an efflorescence upon the ground and walls in many situations.

EGGS, HATCHING. See Incubation, Artificial.

EIDER DOWN, is a kind of precious down, so called because it is obtained from the *Eider*-duck. These birds build their nests among precipitous rocks, and the female lines them with fine feathers plucked from her breast, among which she lays her five eggs. The natives of the districts frequented by the eider-ducks let themselves down by cords among the dangerous cliffs, to collect the downs from the nests. It is used to fill coverlets, pillows, cushions, &c.

ELAINE is the name given by Chevreul to the thin oil, which may be expelled from tallow, and other fats, solid or fluid, by pressure either in their natural state or after being saponified, so as to harden the *stearine*. It may be extracted also by digesting the fat in 7 or 8 times its weight of boiling alcohol, spec. grav. 0·798, till it dissolves the whole. Upon cooling the solution, the stearine falls to the bottom, while the elaine collects in a layer like olive oil, upon the surface of the supernatant solution reduced by evaporation to one eighth of its bulk. If this elaine be now exposed to a cold temperature, it will deposit its remaining stearine, and become pure. See Fat, Oils, and Stearine.

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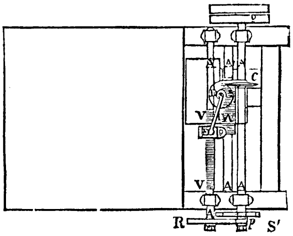
ELASTIC BANDS. (*Tissus Elastiques*, Fr.; *Federharz-zeige*, Germ.) The manufacture of braces and garters, with threads of caoutchouc, either naked or covered, seems to have originated, some time ago, in Vienna, whence it was a few years since imported into Paris, and thence into this country. At first the pear-shaped bottle of Indian rubber was cut into long narrow strips by the scissors; a single operative turning off only about 100 yards in a day, by cutting the pear in a spiral direction. He succeeded next in separating with a pair of pincers the several layers of which the bottle was composed. Another mode of obtaining fine threads was to cut them out of a bottle which had been rendered thin by inflation with a forcing pump. All these operations are facilitated by previously steeping the caoutchouc in boiling water, in its moderately inflated state. More recently, machines have been successfully employed for cutting out these filaments, but for this purpose the bottle of caoutchouc is transformed into a disc of equal thickness in all its parts, and perfectly circular. This preliminary operation is executed as follows: 1. the bottle, softened in hot water, is squeezed between the two plates of a press, the neck having been removed beforehand, as useless in this point of view; 2. the bottle is then cut into two equal parts, and is allowed to consolidate by cooling before subjecting it to the cutting instrument. When the bottle is strong enough, and of variable thickness in its different points, each half is submitted to powerful pressure in a very strong cylindrical mould of metal, into which a metallic plunger descends, which forces the caoutchouc to take the form of a flat cylinder with a circular base. The mould is plunged into hot water during the compression. A stem or rod of iron, which goes across the hollow mould and piston, retains the latter in its place, notwithstanding the resilience of the caoutchouc, when the mould is taken from the press. The mould being then cooled in water, the caoutchouc is withdrawn.

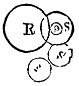
The transformation of the disc of caoutchouc into fine threads is performed by two machines; the first of which cuts it into a riband of equal thickness in its whole extent, running in a spiral direction from the circumference to the centre; the second subdivides this riband lengthwise into several parallel filaments much narrower but equally thick.

The following *figs.* 473, 474, 475, represent the machine for cutting the spiral riband. The disc D, placed horizontally, turns round its vertical axis, so as to present its periphery to the edge of a knife C, formed like a circular blade, whose plane is perpendicular to that of the bases of the disc. This knife turns round its centre, which is fixed. The rotatory motion of the disc forces the knife to penetrate further and further into its mass, and the motion of the knife itself makes it cut the riband more easily. It is obvious, that if the disc alone revolve, the motionless knife could act only by pressure, and would meet with an enormous resistance. A third movement becomes necessary. In proportion as the disc is diminished by the removal of the spiral band, the centre of this disc must advance upon the knife, in order that the riband may have always the same breadth. The inspection of *fig.* 475 will make the accordance of the three motions intelligible.

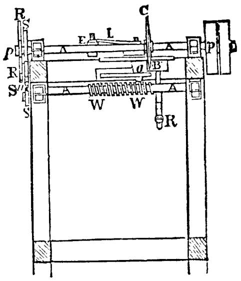
473



475



474



The knife C is placed upon a shaft or axis A, which carries a pulley, round which a belt or cord runs which drives the whole machine. This knife is six inches in diameter. In order that by being kept cool it may cut the caoutchouc better, it is plunged at its lower part into a trough B, full of water; a stopcock R, serves to empty this trough.

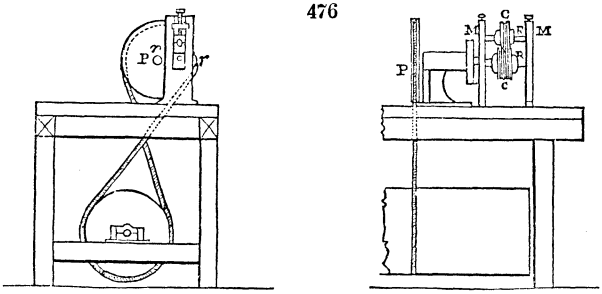
The shaft A bears a pinion p, which takes into a wheel R, placed upon the shaft A′; upon which there is cut a worm or endless screw, V, V. This worm bears a nut E, which advances as the screw turns, and carries with it a tie L, which in its turn pushes the disc D, carried upon a shoulder constantly toward the knife. This shoulder is guided by two ears which slide in two grooves cut in the thickness of the table. The diameter of the pinion p is about one fifth of that of the wheel R; so that the arbor A turns five times less quickly than the arbor A′; and the fineness of the screw v contributes further to slacken the movement of translation of the disc.

When the disc is all cut down, the shoulder, the tie, and the nut, are brought back to their original position by lifting the nut, which is hinged on. The disc is fixed upon the shoulder by means of sharp points, and an upper washer. The shoulder and the washer have a very small diameter, in order that the knife may, in cutting down the disc, advance as near as possible to the centre.

The rotatory movement of the disc and its shoulder, is given by an endless screw W, W, which governs a pinion *p*′, provided with 10 teeth, and carried by the shaft A, upon which the shoulder is mounted. The arbor A′ of this endless screw receives its motion from the first shaft A, by means of the wheels S and S′ mounted upon these shafts, and of an intermediate wheel S″. This wheel, of a diameter equal to that of the shaft A″, is intended merely to allow this shaft to recede from the shaft A. The diameter of the wheel of this last shaft is to that of the two others in the ratio of 10 to 8.

Second machine for subdividing the ribands. Fig. 476.—The riband is engaged between the circular knives, C, C, which are mounted upon the rollers R, R; thin brass washers keep these knives apart at a distance which may be varied, and two extreme washers mounted with screws on each roller maintain the whole system. The axes of these rollers traverse two uprights M, M, furnished with brasses, and with adjusting screws to approximate them at pleasure. The axis of the lower roller carries a wheel *r*, which takes into another smaller wheel *r*′, placed upon the same shaft as the pulley P, which is driven by a cord. The diameter of the wheel *r* is three times greater than the wheel *r*′. The pulley P is twice the size of the wheel *r*′; and its cord passes round a drum B, which drives the rest of the machine.

476



The threads, when brought to this state of slenderness, are put successively into tubs filled with cold water; they are next softened in hot water, and elongated as much as possible in the following manner:—They are wound upon a reel turned quickly, while the operative stretches the caoutchouc thread with his hand. In this way it is rendered 8 or 10 times longer. The reels when thus filled are placed during some days in a cold apartment, where the threads become firm, and seem to change their nature.

This state of stiffness is essential for the success of the subsequent operations. The threads are commonly covered with a sheath of silk, cotton, or linen, by a braiding machine, and are then placed as warp in a loom, in order to form a narrow web for braces, garters, &c. If the gum were to exercise its elasticity during this operation, the different threads would be lengthened and shortened in an irregular manner, so as to form a puckered tissue. It is requisite therefore to weave the threads in their rigid and inextensible, or at least incontractile condition, and after the fabric is woven to restore to the threads of caoutchouc their appropriate elasticity. This restoration is easily effected by passing a hot smoothing iron over the tissue laid smoothly upon a table covered with blanket stuff. See BRAIDING MACHINE.

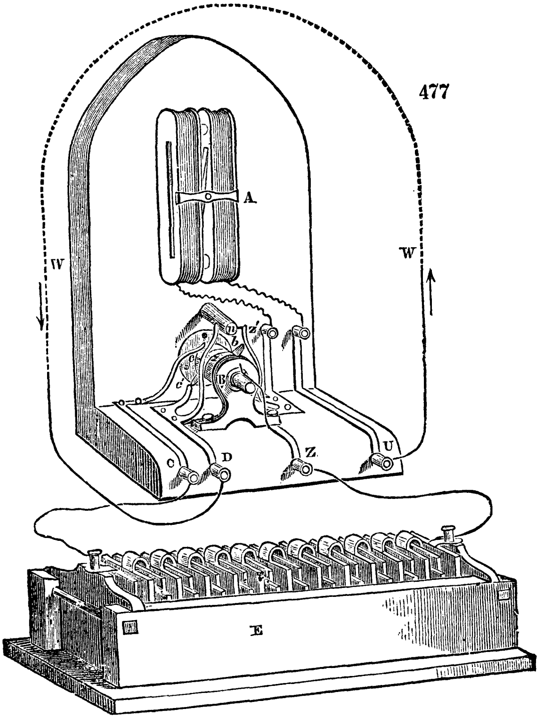
ELECTIVE AFFINITY (*Wahlverwandtschaft*, Germ.) denotes the order of preference, so to speak, in which the several chemical substances *choose* to combine; or really, the gradation of attractive force infused by Almighty Wisdom among the different objects of nature, which determines perfect uniformity an identity in their compounds amidst indefinite variety of combination. The discussion of this interesting subject belongs to pure chemistry. See DECOMPOSITION.

ELECTRO-TELEGRAPHY. *Magnetic Needle Telegraphs.*—After Œrsted had discovered the mutual action of electric currents and magnetic needles, Ampere "proposed, in consequence of an idea suggested to him by the illustrious Laplace, to employ as many circuits as there were letters of the alphabet, and to make each of them act on a separate needle."

Schweiger's invention of the galvanometer, followed more recently by Wheatstone's discovery of the velocity of electricity, gave renewed impulse to these inquiries. Professor Ritchie illustrated Ampere's idea on a small scale, but rather with a view of pointing out the difficulties which enveloped it than to propose it for practical purposes. Alexander's telegraph had thirty galvanometric needles and thirty-one wires; each needle supported a screen, which it carried with it when deflected, and thus exposed a letter. Davy's first telegraph was of the same character, only the letters were illuminated. Baron Schelling and Fechner proposed to limit this number by employing fewer needles and observing their combined motions, a different character being indicated according to the number of needles in motion.

Mr. Bain has proposed to fix the magnet and deflect the coil. The arrangements peculiar to Mr. Wheatstone's needle telegraph are, that he has one wire only for each needle; that two needles are thus always included in the circuit; that the combination of the two needles out of five, which he generally used, will produce 20 signals, and that by a key-board, peculiarly his contrivance, these several circuits can be readily formed. By combining three or four needles, 200 signals can be given. As the motion of these deflected needles was not of itself sufficiently violent to ring a bell in order to call attention, arrangement was made that one of the needles by its deflection should complete the circuit of a distant battery, and this would then make an electromagnet, and liberate the detent of an alarm. Other modes of sounding an alarm were adopted on account of the difficulties which attended the early experiments on that form of telegraph which we shall presently describe. As it is not the intention to give here a history of telegraphs, the above illustrations of the chief applications of the galvanometer to this purpose will suffice.

"The instruments to be first described are the inventions of Messrs. W. Fothergill Cooke and Charles Wheatstone, F.R.S. They are of two kinds: the one, in which a



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single galvanometer is employed; the other, in which there is a pair of galvanometers The former will serve our present purpose, as the mechanical adjustments of the latter are merely the double of this. I have removed the case from the instrument in order to give a clear view of all the essential parts; and have engraved a back view of it (*fig.* 477) with the battery E attached as if for use; and the circuit of the galvanometer A completed by the wire W W.

"The instrument is possessed of a two-fold character; it is *passive*, or ready for receiving signals from another instrument; it is *active*, or ready for transmitting signals to another instrument. By describing first how it is fitted for *receiving* signals, and then how it is arranged for *transmitting* them, we shall be better able conveniently to analyze it, and to comprehend its general structure. The frame of the coil B is of brass, or (which is in many respects better) of polished wood or of ivory; it is screwed upon the face of the instrument, which face is a brass plate varnished on the inner side. Looking at the coil, a short wire from its right-hand end comes to a screw terminal, which latter, by a slip of brass neatly laid on the instrument case, is connected with another terminal U. The left-hand end of the coil comes also to a terminal, from which a slip of brass descends to a brass plate here, partly hidden; but its form may be gathered from a similar plate, visible on the left side. These twin plates are in metallic connection by means of the two upright springs, plainly shown in the drawing. The springs are of stout steel, and press strongly on two points in a short insulated brass rod *n*, which is screwed in the wooden framework of the instrument. The left-hand plate is connected with the terminal D, also by a slip of brass. If now, the two terminals U and D are connected by a wire W W, the circuit will be complete, as follows: from the terminal U into the coil at the right-hand side; out of the coil, at the left-side downwards to the right-hand plate; up the right-hand steel spring, across the brass rod *n* to the left-hand steel spring; downward by this spring to the left-hand plate, thence by the slip of brass to the terminal D, and thence by the wire W W the terminal U, whence we started. If now the wire from U went up the line of railway, and the wire from D down the line, and the circuit were in some way kept complete on the large scale, as it has been here described on the small scale, any electric current passing along the wire from a distant station, would traverse this coil in its course, would deflect the needle, and so make a signal. I should here mention that for the sake of regularity, we adopt one unvaried order in attaching wires to the instrument; it is to put the up wire on the terminal, shown by U on the figure, the coils being all uniformly wound.

"So far for receiving a signal—now for sending one. Were we to go out on the open railway, taking with us a battery, and to cut any one of the wires, and place its two ends, thus obtained, upon the two terminal ends of the battery, a current would pass along the line, and the needles on that wire would be deflected; and if we changed hands so as to reverse the connections, the deflections of the needle would be reversed. The same would happen were we to cut a wire inside the office, or inside the telegraph, and to treat it in a similar way. Now, in every apparatus contrived for transmitting signals, we have a *place corresponding to such a cut wire;* and near this place are the poles of the battery, mounted and moveable, so that they may be readily applied in the breach, one way or other as required. The place here (*fig.* 477) is the top of the springs. They are not *joined* to the brass rod *n;* but, as I said before, *press hard* upon it, and can readily be raised with the finger, or otherwise. It is obvious that, when either of them is raised, the circuit is broken. Now, near this place is a mechanical contrivance, by which the poles of the battery may make a breach in the circuit, and be applied in the breach in either direction. The drum B is of box-wood, the ends *c* and *z* being capped with brass, and insulated from each other by the wood, *b*, left between them. The drum is moveable by a handle, not in sight here, and is supported as shown in the present figure. A stout steel wire *c′* is screwed beneath into the *c* end of the drum; and a similar *z′* is screwed above into the *z* end. These two wires are the poles of the battery, *z′* being connected with the zinc end, and *c′* with the copper, thus:—from the copper end of the battery a wire is led to the terminal C; thence a slip of brass leads to a curved brass spring which presses closely on the drum at *c;* from the zinc end of the battery a wire goes to the terminal *z*, and thence a slip of brass leads to a similar curved spring, pressing on the continuation of the *z* end of the drum, as shown in the figure. It will be seen that, whenever the drum is moved, the steel wire *z′* will lift up one or other of the upright steel springs; it is now lifting up the right-hand one, and so breaks the circuit; but, by a little further motion of the drum, the wire *c′* will press upon the boss below, as shown in the figure, and thus there will be a battery pole on each side of the breach, and a signal will be made on this, and on all instruments, connected with it. And, from the peculiar arrangement with the drum, the motion can be changed as rapidly as the hand can move. I have shown the battery connections exactly as they occur in practice; and the connections are such that, if the right-hand springs are moved off, the needle moves to the right, and, if the left, to the left. The needle on the face of the instrument always

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has its north end upward, and the needle within the coil its north end downward, so that if we look at the face of an instrument, and see the top end of the needle move to the right, we may be sure that in the half of the coil nearest to us the current is *ascending*."

Thus the wires are the channels through which electric influences are conveyed to great distances with inconceivable velocity, and the moveable magnets, or galvanometers, to which the wires are attached at the stations, are the parts of the apparatus by which signals are made. The mode of interpreting these signals is thus described by the author:—

"Double-needle Code.—Having described the apparatus and means employed for producing at pleasure the transmission of signals to distant places, it now remains to us to explain the manner of interpreting these signals, so that each person shall understand the ideas the other would convey.

"We have to describe how, out of only *two* needles, each of which has but *two* movements, the telegraph alphabet is formed. On the face of the instrument are the letters of the alphabet arranged, as it will be seen, *seriatim* in two lines, beginning at the left, and ending at the right, as in writing. The commencing series from A to P is above the top end of the needles; and the concluding series from R to Y below the bottom end. It will also be seen that some letters are engraved *once*, some *twice*, and others *three* times. To make a letter engraved once, requires *one* motion of the needle; to make one engraved twice, *two* motions of the needle; and to make one engraved three times, *three* motions. In respect to the upper row, the needle *nearest* to the letter is moved, and it is moved so as to point *toward* the letter. In respect to the lower row, *both* needles are moved, and their *lower* end is made to point in the direction of the letter required. Six of the letters C, D, L, M, and U, V, require a twofold motion of the needle or needles, first to the right then to the left for C, L, and U, and first to the left then to the right for D, M, and V. These six letters are engraved *intermediate*, and with a double row between. The alphabet produced by this arrangement is of a simple character, and is very readily acquired. To the stranger it appears confused; but when he has the key to it the difficulty disappears; it might at first sight appear that a dial instrument—a telegraph, that is, provided with alphabets engraved on a circular dial, and an index made to revolve, and point to any required letter, is more simple; several such telegraphs exist; and among them are some very happily arranged; and there is something so simple in the fact of being able to point to any desired letter, that it is no wonder the public generally may, on a hasty glance, and before studying the practical merits of the case, be ready to decide in their favor, and prefer them to any other plan, the A, B, C of which is less obvious.

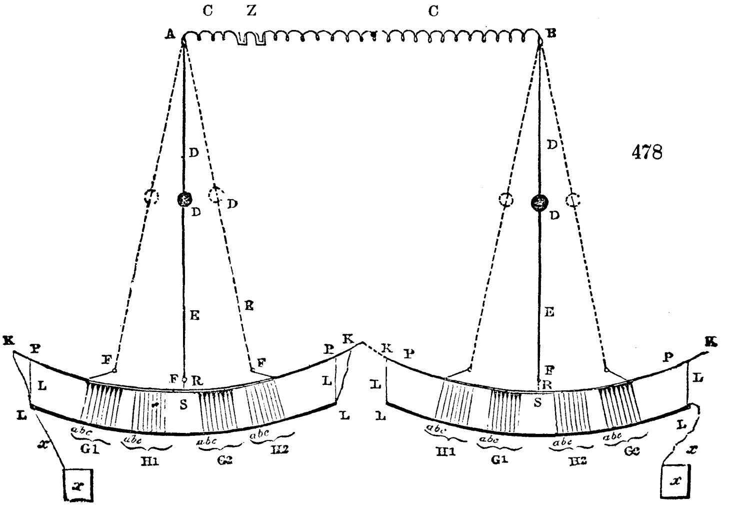
"But is it such a *very* serious matter to learn another alphabet? Every schoolboy, now-a-days, knows some half-dozen alphabets; there are ROMAN letters large, and Roman letters small; *MANUSCRIPT* letters large, and *manuscript* letters small; **Old English** large, and *Old English* small; Greek large, and *Greek* small, and so on, and all different, and not one of them in which the letters are represented by so few *strokes of the pen* as are the telegraph letters by *beats of the needle.* Take one of our plainest alphabets as an example; the ROMAN CAPITALS, for instance, and place a few of them in juxta-position with the corresponding telegraph signals:—

A	\\	E	/	G	///
B	\\\	F	//	H	\

"The simplicity of these symbols is obvious. Two diagonal and one horizontal line are required for the Roman A; two diagonal lines for the telegraph A; one vertical and three horizontal lines make the Roman E; one diagonal the telegraph E, and so on; the difference being that all the world have learned the Roman alphabet, and only a chosen few have studied the telegraphic symbols. That the latter really are simple and distinctive: that they are full of meaning and very legible; that they are applicable to ordinary language, and good, ay, very good! no one will for a moment doubt, who has seen the rapidity and accuracy with which a telegraph officer receives a dispatch.

"To one who sees a telegraph in operation for the first time, the effect borders on the marvellous; setting out of the question the fact that the needles are caused to move by an individual perhaps a hundred miles off; the motion of the needles hither and thither; quicker than the untrained eye can follow; the want of all apparent order and rule in their movement; the ringing of the changes between one and the other, and both; the quiet manner in which the clerk points his needle to the letter E, in rapid intervals, implying that he understands the word; while, to the uninitiated looker-on, all is wonder and mystery, and confusion; and the rare occurrence of the clerk pointing to ✠, implying he did *not understand;* and, finally, the quiet manner with which the clerk tells you, very coolly, as the result of his operations, "That the very pretty girl, with bright blue eyes and long curls, *has* sailed for Boulogne in the *Princess Clementine*, now leaving Folkstone Harbor; and that she *is* accompanied by the tall, handsome man, with the dark moustache and military cloak.' As he tells you this, and says, 'Message and answer, forty words two rates at 10*s.* 6*d.*, one guinea, porterage a shilling—one pound two.' If you happen to be the papa of the pair of blue eyes, you are bewildered, and wish you were an electric current, and could be sent after them."—*From Electric Telegraph Manipulation, by C. V. Walker.*

An invention apparently very simple and comprehensive for electro-telegraphic correspondence, was made the subject of a patent in February, 1851, in Newton's Journal. It consists in the use of such parts or arrangements of apparatus as will allow two or more persons, by the agency of electricity, to send or receive signals or intelligence by one common wire of communication or main conductor, whilst the rapidity or closeness in the order of succession of the signals, consequent on the indefinite short time the main conductor is in actual use in conveying the electric current for transferring the signal shall be such, that all the persons so employed in these telegraphic operations can be continually and simultaneously occupied, in like manner as if each one of them had a distinct wire of communication all the time waiting for or appropriated to his particular use. By this invention the same practical telegraphic results are obtained, through agency of the one wire or main conductor, as, in the varieties of the electric telegraph before known or used, would require several distinct wires of communication. According to this improved plan of working, the wire of communication or electric conductor may be considered as a public word road, or an omnitelegraphic way; whereas, in contradistinction, the conductor, as heretofore used, may be considered a private word road, or a unitelegraphic way. In addition to the ability of allowing divers parties simultaneously to telegraph at will either all in the same or in contrary directions, over or along one wire of communication, this improvement enables each one of the operators, so employed, to have and to use as many distinct short wires or accessory conductors, all related to the main conductor, as the operators may desire to have separate signals; whereby the facility of making and receiving or recording signals or intelligence is greatly increased. Thus, for example,—suppose ten men at each end of the wire of communication are all using the same wire of communication which connects the distant places, their practical telegraphic facilities would be greater than could be had by the old system, if these twenty men had twenty different wires of communication in place of only one such wire; and would be as great as could be had by the old system, if each of those twenty men had as many such wires as they might desire to make or receive different signals. Thus, supposing twenty-five signals to be made and twenty-five to be received, for each of these twenty men, 1,000 separate wires or main conductors would be required, in order to accomplish what, by the new system, requires only one such main conductor, aided by 1,000 short wires or accessory conductors, or signal-making and signal-receiving wires, which need be of but a few inches in length severally, or so long as to reach to, or be systematically put into, electric relation with the respective ends of the main conductor or wire of communication; or, otherwise by motion be successively brought into electric communication with, and so momentarily forming in succession, portions of the conductor, by which the electric current, circuit, or line of inductive action is established, maintained, or broken, from time to time. It may be stated that this improvement rests upon taking advantage of the circumstance that, practically speaking, no sensible portion of the time employed in working the telegraph is expended in the actual transmission of the electric influence, which is the medium or agent of the communication, but that is due to the operation of making or recording the signals. One wire, reaching between the distant places, is therefore capable of being the instrument of transmitting an indefinite number of different signals in a second of time, provided that suitable adaptations are made to enable so many different signals to be separately placed upon one end of the main conductor, and received or recorded at the other end of the conductor, in an intelligible manner. There are an indefinite number of methods of applying to practice this improvement, differing more or less in kinds of apparatus used, and in modifications of electrical actions applied. But all are substantially the same improvement; inasmuch as their action would be to set apart distinct and small and successive fractions of a second or other period, and assign and apply such small fractions of time to different uses or for different persons; so that, although many persons should all simultaneously be employed in using one common wire of communication, yet all the signals so transmitted by it may be successive; the rapidity of the electric conduction admitting, by this invention, the divers signals to be transmitted successively along the wire, and yet so quickly the one after the other, as to give a like practical result, as if they were simultaneously transmitted by separate wires or main conductors. A convenient mode of applying this improvement to practice, and for illustrating the principle of the invention, may be understood by referring to the diagram (*fig.* 478), wherein two pendulums, supposed to be actuated by clock work or other suitable means, are indicated; such pendulums being made to vibrate as nearly as possible together in position and in time of vibration. At the chief station A, the standard pendulum is situate; and the dependent telegraph station is also provided with a pendulum, as at B. D, D are the pendulum rods, with these balls or weights; E, the prolonged end of the pendulum rods, which should be much longer in proportion than represented in the drawing; F, slight springs, united to the prolonged end of the pendulum rods; and P, R, P, and P, S, P, are two grooves or pathways, so made that the spring F shall fall into the groove P, R, P, when the pendulum makes the vibration from left to right, and shall fall into the groove P, S, P, when making the vibration from right to left; C, C, is the main conductor or wire of communication, connecting the two telegraphic stations A and B together; X, X, are ground plates and ground wires. At station A, there are metallic points over which the spring F passes, touching the surface each vibration,—which points are connected with the conductors L, X. The groove P, R, P, at station B, is of metal, and in electric communication with L and X. The spring F, in moving in either of the grooves P, R, P, or in the P, S, P, of station A, is kept in its path by an insulated or non-conducting guide; Z is a Leyden jar, prime conductor of an electrical machine, or galvanic pile, kept constantly charged, or capable of giving a great number of visible sparks or electric pulsations per second, on making or breaking the electric circuit or line of inductive action. The wire C, C, C, has a metallic connection with the upper end of the pendulum rods, which are also metallic as well as their prolonged terminations. In this condition of things, whenever the spring F, at station A, passes over K, K, in its vibrations, there will be an electric communication or circuit from Z to K, through L, X, to the ground at station A; also from Z to the metallic groove P, R, P, at station B, and to the ground there; provided the pendulum at station B is making its vibration from left to right, when the pendulum at station A carries its spring F over the conducting point K. At K on the left-hand side of the standard pendulum, there are two metallic faces near together; by this arrangement it can be known at station B when the pendulum at station A is in motion, and the position of its vibrations exactly determined; so that the pendulum at B can be from time to time set in motion, accelerated or retarded, in order to maintain that degree of synchronism in the action of the pendulums, and similarity of position, which are necessary for success of the telegraphic operations. When the pendulum at B is correctly timed in its motions, there will be visible two sparks on the left-hand side, and one spark on the right-hand side, of the conducting groove at K, K, at station B, equal distance from the centre of vibration; but when this pendulum is not in its proper position or motion, these sparks can be seen at other places along the groove. H^1 and H^2, at both stations are signal-making wires; and G^1, G^2, at both stations, are signal-receiving wires. These signal wires are to be supposed as numerous in each set as the number of different signals desired to be used—say not less than the letters of the alphabet; a smaller number is, however, shown in the drawing for distinctness' sake. All the signal-receiving wires reach into the groove or pathways P, S, P, in such a manner, that the spring F shall touch and slide over the flattened faces or ends of these wires in succession each time he pendulum moves from right to left. The signal-making wires on the contrary,



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stand a little off, out of the groove or pathway, but are intended to be so mounted that each may be raised with the pressure of the finger, and brought into the line of the groove or pathway, to be touched by the spring F, when the pendulum swings from left to right. All these signal wires are united by one end to the conductor L, L, but are free and independent at the other end. The free end of the signal-receiving wires may have a width of half an inch, more or less, where F passes over them. The corresponding ends of the signal-making wires may be put on edge or line; so that the signal-making wires can be touched by F but for a moment, whilst the signal-receiving wires will be touched for a sensible time by F, in passing over them.

Under these circumstances, if any one of the signal-making wires H1, at station A, be touched and brought into contact with the end F, of the vibrating pendulum, a conducting circuit or electric current will be established for the moment, the corresponding pendulum at station B will be in front of the group of signal-receiving wires H1 of that station. Therefore, from the electric circuit existing for that moment of contact, there would be a spark visible upon the flattened end of that one of the signal-receiving wires which corresponds to that one of the signal-making wires at the other station, which may have been pressed upon and brought into the pathway of F; all these signal wires in each set being marked by and signifying the different letters of the alphabet, &c. It is obvious, that if the left-hand wire of each set be marked *a*, the next *b*, next *c*, &c., then, should *a*, *b*, or *c*, of a signal-making group H1, station A, be pressed upon and touched by F, this act will be known at station B, by the appearance of a spark on the end of that one of the signal-receiving wires *a*, *b*, or *c*, of group H1 station B, corresponding to that wire which may have been so touched at station A. Thus, at will, can any signal or letter be sent from station A to station B, and during the operation of signal-making, by one person at station A, to another at station B. It will now be seen that another person, or the same person at station B, by the use of the wires H1, can telegraph in reply to station A, by making use of the set of wires H1 of each station, in a manner similar to those in which the wires H1, before described, were used. Suppose that the time of a double vibration of these pendulums is equal to the time necessary for conveniently making and observing a signal, then, by the use of the four sets of signal wires above named, a person may send to or receive signals from or between stations A and B reciprocally; or four persons may be continually and simultaneously employed in making and receiving signals at each station. The use of these signal-wires referred to, as able to employ four persons in continual telegraphic intercourses, will in no way interfere with the simultaneous employment of two or four other operators using the other signal wires on the right-hand half of the vibrations marked H2 and G2; so also by lengthening out the ends of the pendulum rods, or increasing the angular motion of the pendulums, more space or places may be had for carrying out a larger number of telegraphic operations indefinitely.

It has been said that the pendulum at station B may be kept adjusted to the motions of the regulating pendulum, by the appearance of sparks at K, K; but this synchronism may be more perfectly maintained by using any of the known forms of electro-magnets. In the above illustration the electric spark from an electrical machine has for simplicity been chosen as the visible signal; but should it be desired to make signals by the hydro-electric current and the deflection of a needle, then each one of the signal-receiving wires, before uniting with the common conductor L, may be lengthened out sufficiently to form the coil of a galvanometer; and the current passing through any one of these wires can make itself known, or a signal be so given, by the deflection of the needle of the galvanometer belonging to that particular signal-receiving wire so signalized; or, in like manner, those prolonged signal-receiving wires may each one enclose a bar of iron, in place of a magnetic needle, so as to have an electro-magnet and keeper belonging to each one of these wires; then the passage of the current through any of the wires may give magnetism to the bar, or actuate the magnet or its keeper; and from this motion the signals may be perceived, or recorded and printed in any convenient form. From the above explanations, it will be obvious that divers stations and complex systems of telegraphic lines of communications can be established on the principle of this invention; and it will be also understood, that the invention is susceptible of an indefinite number of modifications or forms, as respects the apparatus employed in carrying it into use. The patentee claims, rendering available conducting power of electric telegraph wires, so that they may transmit one or more electric currents (in the same or opposite directions) during the time that must necessarily elapse between the transmission of succeeding signals which have reference to one and the same communication.—*Newton's Journal*, xl. 36.

ELECTRO-GILDING AND SILVERING. According to Le Docteur Philipp, the vessel required for this purpose should be made of the same material as that commonly employed for flower-pots: before being used it must be tested in the following manner: On being filled with water, if it becomes simply damp, without allowing the water to filter through it, it is fit for use, but not otherwise. This vessel is surrounded by a cylinder of zinc, and then introduced into another vessel (a wooden tub for instance) containing dilute sulphuric acid. The earthen vessel is intended to contain the solution of gold or silver, and is furnished with a web of copper wire, which is made to communicate with the zinc by means of one or more conducting wires. The objects to be gilt or silvered are placed upon the net-work. The earthen vessel containing a zinc cylinder, and some hydrochloric acid, is introduced into another vessel, containing the solution of gold or silver, placed in the centre of a wire web partition, which communicates with the zinc cylinder by means of a conducting wire. In the first case, the articles which are to receive the thickest coating are placed nearest the outer sides of the apparatus; in the second, nearest to the earthen vessel: in both cases it is advisable to shift their position occasionally. By combining these different arrangements, the deposit obtained is more abundant, and more equally distributed upon the surface to be gilded or to be silvered. For this purpose an opening is made in the centre of the web in which the zinc cylinder is inserted, with connecting wires to the web. When the articles to be operated upon can be easily suspended from a given point, the web of the apparatus may be made with wider meshes, and the articles suspended vertically between them. Dr. Philipp prefers a single galvanic arrangement to a battery, as it affords more solid deposition.

ELECTRO-METALLURGY. By this elegant art perfectly exact copies of any object can be made in copper, silver, gold, and some other metals, through the agency of voltaic electricity. The earliest application of this kind seems to have been practised about 16 years ago, by Mr. Bessemer, of Camden Town, London, who deposited a coating of copper on lead castings, so as to produce antique heads in relief, about 3 or 4 inches in size. He contented himself with forming a few such ornaments for his mantelpiece; and though he made no secret of his purpose, he published nothing upon the subject. A letter of the 22d of May, 1839, written by Mr. J. C. Jordan, which appeared in the *Mechanics' Mag.* for June 8, following, contains the first printed notice of the manipulation requisite for obtaining electro-metallic casts; and to this gentleman, therefore, the world is indebted for the first discovery of this new and important application of science to the uses of life. It appears that Mr. Jordan had made his experiments in the preceding summer, and having become otherwise busily occupied, did not think of publishing till he observed a vague statement in the Journals, that Professor Jacobi, of St. Petersburg, had done something of the same kind. Mr. Jordan's apparatus consisted of a glass tube closed at one extremity with a plug of plaster of Paris, and nearly filled with a solution of sulphate of copper. This tube, and its contents, were immersed in a solution of common salt. A plate of copper was plunged in the cupreous solution, and was connected by means of a wire and solder, with a zinc plate dipped in the brine. A slow electric action was thus established through the moist plaster, and copper was deposited on the metal in a thin plate, corresponding to the former in smoothness and polish; so that when he used an engraved metal matrix, he obtained an impression of it by this electric agency. "On detaching the precipitated metal," says he, "the most delicate and superficial markings, from the fine particles of powder used in polishing to the deeper touches of a needle or graver, exhibited their correspondent impressions in relief with great fidelity. It is, therefore, evident that this principle will admit of improvement, and that casts and moulds may be obtained from any form of copper. This rendered it probable that impressions might be obtained from those other metals having an electro-negative relation to the zinc plate of the battery. With this view a common printing type was substituted for the copper-plate, and treated in the same manner. This, also, was successful; the reduced copper coated that portion of the type immersed in the solution. This, when removed, was found to be a perfect matrix, and might be employed for the purpose of casting, where time is not an object. Casts may probably be obtained from a plaster surface surrounding a plate of copper, &c."

On the 12th of September following the above publication, Mr. Thomas Spencer read a paper "On Voltaic Electricity applied to the purpose of working in Metal,' before the Polytechnic Society of Liverpool; which he had intended to present to the British Association at Birmingham in the preceding August, but not being well received there, he exhibited merely some electro-metallic casts which he had prepared. The society published Mr. Spencer's paper, and thereby served to give rapid diffusion to the practice of electro-metallurgy.

One of the most successful cultivators of this art, has been Mr. C. V. Walker, secretary to the London Electrical Society. He has published an ingenious little work in two parts, entitled *Electrotype Manipulation*, where he presents, in a lucid manner, the theory and practice of working in metals, by precipitating them from their solutions through the agency of voltaic electricity. His first part is devoted to the explanation of principles, to the preparation of moulds, to the description of the voltaic apparatus to be used, to bronzing, to coating busts with copper, to the multiplication of engraved plates, and to the deposition of other metals.

Fig. 479. represents a single-cell voltaic apparatus for electro-metallurgy. *z* is a rod of amalgamated zinc, *m* is the mould on which the metal is to be deposited; *w*, is the wire joining them; *c* is a strong solution of sulphate of copper in the large vessel; *p*, is a tube or cylinder of porous earthenware, standing in the other, and containing dilute sulphuric acid. The solution of blue vitriol is kept saturated, during the progress of its depositing copper, by piling crystals of the salt upon the shelf, shown by the dots under *p*. The mould to be coated should not be too small in reference to the surface of zinc under voltaic action. The time for the deposition to be effected depends upon the temperature; and is less the higher this is within certain limits; and at a freezing temperature it ceases almost entirely. When a mould of fusible metal is used, it should not be placed in the voltaic apparatus till everything is arranged, otherwise oxide will be deposited upon it, and spoil the effect. When the circuit is completed the mould may be immersed, but not before. Wax moulds are rendered electric conductors, and thereby depositors as follows: After breathing on the wax, rub its surface with a soft brush dipped in plumbago; breathing and rubbing alternately till the surface be uniformly covered. Attach a clean wire to the back of the mould, connecting it by plumbago with the blackened wax. Sealing-wax is coated in like manner. Casts of Paris plaster are first well imbued with melted wax or tallow, and then black-leaded. Objects in Paris plaster should be thoroughly penetrated with hot water, but not wet on the surface, before wax casts are made from them. Moulds are best taken from medals in stearine (stearic acid). For plating and gilding by electro-chemical agency, the following simple plan of apparatus is used. *Fig.* 480, is a rectangular porcelain vessel, which contains in its centre a porous cell for containing the solution of oxide of silver or gold, by means of cyanide of potassium; and this porous cell is surrounded at a little distance by a similarly formed vessel of zinc. The connexion is formed between the zinc and the suspended object to be coated, either by a pinching screw, or by the pressure of its weight upon the wire. The dilute acid which excites the zinc should, in this case, be very weak, in reference to the strength of the cyanide solution, which should be recruited occasionally by the addition of oxide.

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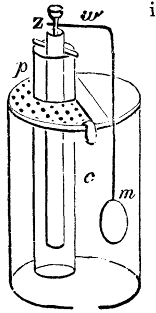
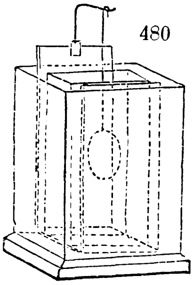


It has been found that with cyanide solutions of gold and silver in the electro-chemical apparatus, the nascent cyanogen at the positive pole or plate, in a decomposition cell, will act upon and dissolve gold and silver. Two or three of Daniell's cylindric cells, as shown at *a* in *fig.*481, of a pint size, for acting upon solutions of gold or silver, will in general suffice. The decomposition cell *b* is made of glass or porcelain. The zinc may be amalgamated, and excited with brine; the copper cell contains, as usual, a solution of blue vitriol. To the end of the wire attached to the copper cylinder of the battery, a plate of silver or gold is affixed; and to the end of the wire attached to the zinc cylinder is affixed the mould, or surface, to be plated or gilt. The plates of silver or gold and zinc should be placed face to face as shown in the figure in the decomposition cell; which is filled by the cyanide solution. A certain degree of heat favors the processes of electro-gilding and plating. The surface is dead as first obtained, but it may be easily polished with leather and plate-powder, and burnished in whole or in parts with a steel or agate tool.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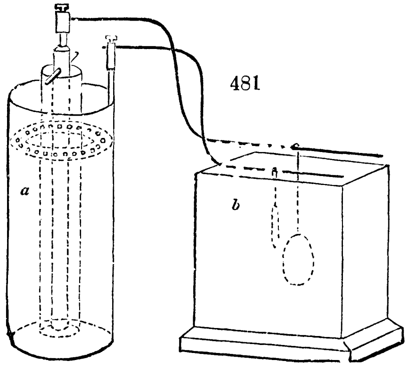
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In March, 1840, Messrs. Elkington obtained a patent for the use of *prussiate of potash*, as a solvent for the oxides of gold and silver in the electro-chemical apparatus for plating and gilding metals. They also "sometimes employ a solution of protoxide (purple of Cassius) in the muriates of potash, &c." The chemical misnomers, in their specification, are very remarkable, and do great discredit to the person employed to draw it up. Prussiate of potash is the ordinary commercial name of a salt very different from the cyanide of potassium—the substance really meant by the patentees—and the purple of Cassius is very different from protoxide of gold.

In plating or gilding great care must be bestowed in making the articles clean, bright, and perfectly free from the least film of grease. For this purpose, they should be boiled in a solution of caustic alkali, then scoured with sand and water, next dipped into a dilute acid, and finally rinsed with water. A solution of the nitrate or cyanide of mercury may also be used with advantage for cleaning surfaces. The following metals have been deposited by electro-chemistry:—

Gold, platinum, silver, copper, zinc, nickel, antimony, bismuth, cobalt, palladium, cadmium, lead, and tin; of these, the first five are the most important and valuable. The gilding solution may be prepared by placing slips or sheets of gold in a solution of cyanide of potassium, and attaching to the negative pole of a voltaic battery, a small plate of gold, but to the positive pole a much larger one; whereby the latter combines with the cyanogen, under the influence of positive electricity, and forms a solution. Or, oxide of gold, precipitated from the chloride by magnesia, may be dissolved in the solution of the cyanide.

For making copper medals, &c., a plate of amalgamated zinc is to be put into a vessel of unglazed earthenware, or of any other porous substance, filled with dilute sulphuric acid; which vessel is set into a trough of glass, glazed pottery, or pitched wood, containing blue vitriol in the state of solution, as well as in the state of crystals upon a perforated shelf, near the surface of the liquid.

The moulds to be covered with copper are to be attached by a copper wire to the zinc plate. The surface of zinc excited by the acid should be equal to that of the moulds; with which view a piece of zinc, equivalent in size to the mould, should be suspended in front of it.

For depositing copper upon iron, Messrs. Elkington use a solution of ferrocyanide of copper in cyanide of potassium in the decomposition trough, instead of sulphate of copper, neutralized from time to time with a little caustic alkali, as in the common practice of making medals, &c., of copper. I should imagine that the black oxide of copper dissolved in solution of cyanide of potassium would answer better; as the iron in the ferrocyanide might be rather injurious. The iron to be coppered being previously well cleaned from rust, &c., with the aid of a dilute acid, is to be plunged into the cyanide solution heated to 120° Fahrenheit, and connected by a wire with the negative pole of a voltaic battery, as formerly described. In from five to ten minutes, the iron will be completely coated. It is then to be scoured with sand, and plunged into solution of sulphate of copper; whereby it will show black spots wherever there are any defective places. In this case, it is to be cleaned and replaced under the cyanide solution, in the decomposition cell for a minute or two. Zinc may be deposited from a solution of its sulphate by a like arrangement.

Metallic cloth may be made as follows:—On a plate of copper attach quite smoothly a stout linen, cotton, or woollen cloth, and connect the plate, with the negative pole of a voltaic battery; then immerse it in a solution of copper or other metal, connecting a piece of the same metal as that in the solution with the positive pole; decomposition takes place, and the separated metallic particles in their progress toward the metal plate or negative pole, insinuate themselves into the pores of the tissue, and form a complete sheet of flexible metal. Lace is metallized by coating it with plumbago, and then subjecting it to the electro-metallurgic process.

The gilding solution should be used in the electric process at a temperature of 130° F. The more intense the electric power, the denser and harder is the metallic coat deposited.

Metallic silver may be combined with cyanogen by subjecting it to the joint action of a solution of cyanide of potassium and positive electricity. Or cyanide of silver may be precipitated from the nitrate by a little cyanide of potassium, and afterward dissolved by means of an excess of cyanide of potassium. The *quantity* of electric power or surface-size of the battery should in all cases be proportioned to the surface of the articles to be placed or gilt, and the electric intensity or number of sets of jars proportioned to the density of the solution. Plating is accomplished in from 4 to 6 hours. The articles should be weighed before and after this operation, to ascertain how much silver they have taken on.

Messrs. Elkington make their moulds with wax, combined with a little phosphorus, which reduces upon their surfaces a thin film of gold or silver, from solutions of these metals, which films are better than the black-leaded surfaces for receiving the copper deposit. They also recommend to add a little alkali to the solution of sulphate of copper, intended to afford a deposite of metal. The single cell, first described above, is best adapted for this purpose.

M. Ruolz employs for gilding, a solution of sulphuret of gold in sulphuret of potassium, which he prepares by precipitating a solution of gold in *aqua regia*, by sulphuretted hydrogen, and redissolving the precipitate with sulphuret of potassium. By the use of this solution of gold, he obtains a very beautiful and solid gilding, and at less expense than with cyanide of potassium. Every metal which is a negative electrode to gold may be gilded.

Platinizing is effected best by means of a solution of the potash-chloride of platinum in caustic potash. 1 milligramme (0·015 grain) covers completely a surface of 50 square centimeters (2 inches square); the film of platinum is only one hundredth of a milligramme thick.

M. Bœttger has shown that we may easily tin copper and brass in the moist way by dissolving peroxide of tin (putty) in hydrate of potash (caustic potash ley), putting at the bottom of the vessel holding that solution some turnings of tin, setting the piece of copper or brass upon the turnings, and making the liquor boil. An electric current is produced by the contact of the dissimilar metals; and as the tin is withdrawn by the copper or brass from the solution, it is restored to it by the turnings. Zinking may be done in the same way; by putting pieces of zinc into a concentrated solution of chlorine, by setting the piece of metal to be zinked in contact with these pieces, and applying heat to the vessel containing the whole.

For certain new methods of constructing and arranging voltaic batteries for electrometallurgic operations, a patent was obtained by Dr. Leeson in June, 1842.

Fig. 482, is a longitudinal section of the battery, and *fig.* 483, a plan view of the frame to which the metal plates are attached. *a* is a rectangular wooden trough, containing a wooden frame *b*, formed with vertical grooves in its sides, to receive a series of porous cells *c, c, c*. The plates of the battery are suspended in the fluid or fluids by brass forks *d, d*, fastened to a wooden frame *e, e*, which rests upon the trough *a*, and is connected to the other frame *b*, by two pins *f*, when they are required to be raised together out of the trough *a, a*.

The battery may be charged as usual with one or two fluids; one of them in the latter case being contained in the porous cells *c, c, c:* and plates of copper and zinc, or any other suitable metals may be employed.

The second improvement consists in cleaning copper and zinc plates after they have been used in a battery, by the employment of a voltaic battery; and also in amalga-

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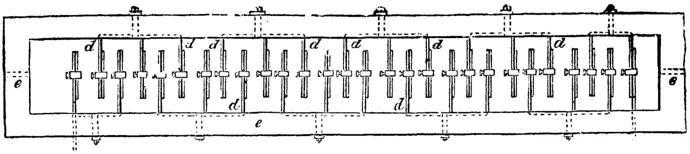

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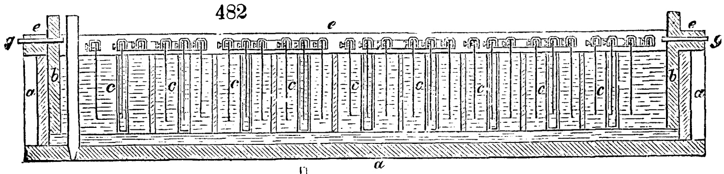

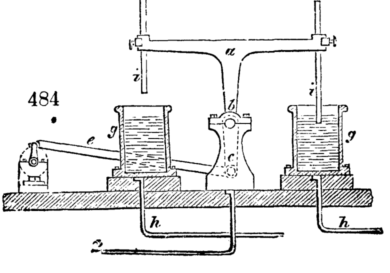

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mating or coating with mercury the surfaces of zinc plates, by the same means to render them suitable for being used in the construction of the voltaic apparatus.

The third improvement consists in exciting electricity by a combination of nitric, sulphuric, or muriatic acid, with any of the following substances; viz, impure ammoniacal or lime liquor of the gas works, solutions of alkaline and earthy sulphurets, the alkalies and their carbonates, or lastly, the acidulous sulphate of iron generated from iron pyrites.

Another of Dr. Leeson's manifold improvements for depositing metallic alloys consists in the employment of one battery, "with the alternating cathode," represented in *fig.* 484. It is composed of a beam, *a*, mounted on the shaft, *b*, which turns in bearings carried by standards, *c;* the beam communicates with the anode of the battery by the wire, *d*, and a vibrating motion is given to it by the rod, *e*, from the shaft, *f*, which is driven by an electro-magnetic engine, or any other suitable prime mover. *g*, *g*, are two vessels containing mercury, connected by wires *h*, *h*, with the cathode plates of the two metals composing the alloy (but if the alloy is to consist of more than two metals, then more vessels, *g*, will be required, one for each cathode plate); these plates are immersed in a solution composed of similar salts of the different metals to be deposited, together with the anode, or surface to be deposited upon, which is connected by a wire with the cathode of the battery. A communication is established between the two cathode plates, or supply of metals, and the anode of the battery, by means of the rods, *i*, *i*, which are caused, by the vibration of the beam, *a*, to dip alternately into either the one or the other of the vessels, *g;* and thus each metal will be deposited on the article to be coated, during the time that the connection is established between it and the battery, by the immersion of its rod into the vessel of mercury. The relative proportions of the two metals is adjusted by lengthening or shortening the rods, *i*, *i*, as shown in the figure, so that they may be immersed for a longer or shorter period in the mercury.

Where the electrical current enters the electrolyte, is the *anode;* where it leads it, is the *cathode.*

The patentee describes ten other improvements, which seem to be ingenious. See *Newton's Journal*, xxii. 292.

ELECTROTYPIE BY THERMO-ELECTRICITY. 1. *For silvering.*—Dissolve 1 troy pound of silver in nitric acid, dilute with a gallon of water, precipitate the silver by solution of carbonate of soda (1 lib.) at 100° Fahr.; wash the precipitate on the filter with warm water. In another vessel dissolve 8 libs. of hyposulphite of soda in 2½ gallons of water at 100°, add 1 lib. of carbonate of soda with the carbonate of silver, stirring until the silver be dissolved. Filter the solution for use. It is advantageous to add 1 lib avoirdupois of hyposulphite, and one-third of a pound of carbonate of soda for every pound troy of silver that may be deposited.

2. *Gold solution.*—One ounce troy of fine gold is dissolved in nitro-muriatic acid, and the solution is evaporated till it assumes a deep red color, and crystallizes upon cooling. Dilute with a pint of pure water and filter. Heat this solution to about 200° Fahr., and precipitate the gold by water of ammonia. Wash the precipitate well on the filter with hot water. Dissolve this gold in 1 gallon of water containing 8 ounces of hyposulphite of soda, and boil together for an hour. The solution when filtered is fit for use. In gilding, this solution may be warmed to about 130° Fahr. A small anode of gold, of about one-tenth the size of the article to be gilded, and a current of two pairs of common galvanic plates, are used.

3. *Copper solution.*—Dissolve 1 pound of carbonate of copper in 8 pounds of hyposulphite of soda, and 1 pound of carbonate of soda dissolved in 2½ gallons of distilled water at 100° Fahr., or thereabouts, and filtered to obtain a clear solution. It is then fit for use, with currents of electricity at 100° Fahr.

Description of the thermo-electric battery.—100 pieces of German silver, containing from 20 to 25 per cent. of nickel, and 100 pieces of iron, each piece being 1 inch broad, 1 foot long, and one-eighth of an inch in thickness. These 200 pieces are soldered to each other, so that iron is always combined with German silver. To get a compact form, 10 rows must be first arranged (every one of 20 pieces or 10 pairs), and these rows must be so soldered to each other that they are parallel, and the whole take the form of a square; taking care that the several pieces are soldered together in such a way that iron will always be in connection with German silver. When the whole is united, it is placed in a rim or frame of iron plate, 1 foot 2 inches high, but so that the metals do not touch each other, nor the iron rim or frame, and fill the rim with plaster of Paris or clay, so that all soldered parts of the series of plates or bars are uncovered, that is, the under ends 1 inch, and the upper ends 3 inches. The clay is covered at the surface with a layer of pitch. The frame containing the series of bars or plates, is so placed that the lower end of the series (1 inch) dip into a sand bath which is heated nearly to redness. The upper ends (3 inches) are to be kept as cold as possible, and for this purpose a current of cold water is caused to flow from one vessel over this battery to another vessel. The upper end of the metals (3 inches) may be covered with a lac or varnish. There is an *anode* wire leading from the German silver plate; and an *artule* wire leading from the iron plate.

The thermo-electric apparatus is intended for the deposition of metals, from the above described solutions.

ELEMENTS (Eng. and Fr.; *Grundstoffe*, Germ.) The ancients considered fire, air, water, and earth, as simple substances, essential to the constitution of all terrestrial beings. This hypothesis, evidently incompatible with modern chemical discovery, may be supposed to correspond, however, to the four states in which matter seems to exist; namely, 1. the unconfinable powers or fluids,—caloric, light, electricity; 2. ponderable gases, or elastic fluids; 3. liquids; 4. solids. The three elements of the alchemists, salt, earth, mercury, were, in *their* sense of the words, mere phantasms.

Denomination of the Substances.	Symbols.	I. Equivalents.		II. Atomic Weights.		III. Equivalents (after Gerhardt and Laurent).	
		O=100.	H=1.	O=100.	H=1.	O=100.	H=1.
Aluminium - - -	Al.	170·900	13·694	170·900	27·388	85·63	13·70
Antimony - - -	Sb.	1612·903	129·269	806·452	129·239	403·25	64·50
Arsenicum - - -	As.	938·800	75·224	469·400	75·224	468·50	75·00
Barium - - - -	Ba.	855·290	68·533	855·290	137·066	425·00	68·00
Bismuth - - - -	Bi.	1330·377	106·600	1330·377	213·200	1312·50	210·00
Boron - - - -	B.	136·204	10·914	136·204	21·828	67·50	10·80
Brome - - - -	Br.	999·620	80·098	499·810	80·098	500·00	80·00
Cadmium - - -	Cd.	696·767	55·831	696·767	111·662	350·00	56·00
Calcium - - - -	Ca.	251·651	20·164	250·000	40·000	125·00	20·00
Carbon - - - -	C.	75·120	6·019	75·120	12·038	75·00	12·00
Cerium (Marignac) - -	Ce.	590·800	47·264	590·800	94·528	—	—
Chlorine - - - -	Cl.	443·280	35·517	221·640	35·517	221·87	35·50
Chromium - - -	Cr.	328·870	26·352	328·870	52·704	162·50	26·00
Cobalt - - - -	Co.	368.650	29·539	368·650	59·078	185·00	29·60
Copper - - - -	Cu.	395·600	31·699	395·600	63·398	198.75	31·80
Didymium (Marignac) -	D.	620·000	49·600	620·000	99·200	—	—
Erbium - - -	E.	—	—	—	—	—	—
Fluorine - - - -	Fl.	235·433	18·865	117·717	18·865	116·85	18·60
Gold - - - -	Au.	2458·330	196·982	1229·165	196·982	1225·00	196·00
Glucinium - - -	G.	87·124	6·981	87·124	13·962	—	—
Hydrogen - - -	H.	12·480	1·000	6·240	1·000	6·25	1·00
Iodine - - - -	I.	1585·992	127·082	792·996	127·082	787·50	126·00
Iridium - - - -	Ir.	1232·080	98·724	1232·080	197·448	—	—
Iron - - - -	Fe.	350·527	28·087	350·527	56·174	175·00	28·00
Lanthanium (Marignac) -	La.	588·000	47·040	588·000	94·080	—	—
Lead - - - -	Pb.	1294·645	103·738	1294·645	207·476	650·00	104·00
Lithium - - - -	Li.	81·660	6·543	81·660	13·086	40·16	6·40
Magnesium - - -	Mg.	158·140	12·671	158·140	25·342	75·00	12·00
Manganese - - -	Mn.	344.684	27·619	344·684	55·238	175·00	28·00
Mercury - - - -	Hg.	1251·290	100·026	1250·000	200·000	625·00	100·00
Molybdenum - - -	Mo.	596·100	47·764	596·100	95·528	—	—
Nickel - - - -	Ni.	369·330	29·594	369·330	59·188	185·00	29·60
Niobium - - - -	Nb.	—	—	—	—	—	—
Nitrogen - - - -	N.	175·060	14·027	87·530	14·027	87·50	14·00
Norium - - - -	No.	—	—	—	—	—	—
Osmium - - - -	Os.	1242·624	99·569	1242·624	199·138	—	—
Oxygen - - - -	O.	100·000	8·000	100.000	16·000	100·00	16·00
Palladium - - -	Pd.	655.477	53·323	665·477	106·646	—	—
Pelopium - - -	Pe.	—	—	—	—	—	—
Phosphorus - - -	P.	392·041	31.414	196·021	31·414	200·00	32·00
Platinum - - -	Pt.	1232·080	98·724	1232·080	197-448	618·75	99·00
Potassium - - -	K.	488·856	39·171	488·856	78·342	243·75	39·00
Rhodium - - -	R.	651·962	52·240	651·962	104·326	—	—
Ruthenium, according to Claus	Ru.	651·000	52·163	651·000	104·326	—	—
Selenium - - -	Se.	495·285	39·686	495·285	79·372	490·90	78·50
Silicium - - - -	Si.	277·778	22·258	277·778	44·516	87·50	14·00
Silver - - - -	Ag.	1349·660	108·146	1349·660	216·292	675·00	108·00
Sodium - - - -	Na.	289·729	23·215	289·729	46·430	143·75	23·00
Sulphur - - - -	S.	200·750	16·086	200·750	32·171	200·00	32·00
Strontium - - -	Sr.	545·929	43·744	545·929	87·488	275·00	44·00
Tantaliam - - -	Ta.	1148·365	92·016	1148·365	184·032	—	—
Tellurium - - -	Te.	801·760	64·244	801·760	128·488	800·00	128·00
Terbium - - - -	Tb.	—	—	—	—	—	—
Thorium - - - -	Th.	743·860	59·604	743.860	119·208	—	—
Titanium - - - -	Ti.	301·550	24·158	301·550	48·316	—	—
Tin - - - -	Sn.	735·294	58·918	735·294	117·836	368·75	59·00
Tungsten - - -	W.	1188·360	95·220	188·360	190·442	600·00	96·00
Uranium - - - -	U.	742·875	59·525	742·875	119·050	750·00	120·00
Vanadium - - -	V.	856·892	68·661	856·892	137·322	—	—
Yttrium - - - -	Y.	—	—	—	—	—	—
Zinc - - -	Zn.	406·591	32·579	406·591	65·158	206·25	33·00
Zirconium - -	Zr.	419·728	33·632	419·728	67·264	—	—

In modern science, the term *Element* signifies merely a substance which has not yet been resolved by analysis into any simpler form of matter; and it is therefore synonymous

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with undecompounded. This class comprehends 62 different bodies, of which no less than 52 are metallic. Five may be styled *Archœal*, from the intensity and universality of their affinities for the other bodies, which they penetrate, corrode, and apparently consume, with the phenomena of light and heat. These 5 are *chlorine*, *oxygen*, *iodine*, *bromine*, *fluorine*. Eight elements are eminently inflammable when acted upon by any of the preceding five, and are thereby converted into incombustible compounds. The simple non-metallic inflammables are *hydrogen*, *azote*, *sulphur*, *phosphorus*, *selenium*, *carbon*, *boron silicon*.

The preceding table exhibits all the undecompounded bodies in alphabetical order, with their prime equivalent numbers, atomic weights, or reciprocal combining and saturating proportions, in reference to oxygen and hydrogen, reckoned 100,000, or 1·0.

The numbers contained in columns I. and II. are deduced from those given by Berzelius, in the fifth edition of his *Lehrbuch ;* and in column III. those atomic weights are added which Gerhardt and Laurent have quoted in the first number of the fifth volume of the *Comptes Rendus.*

The following is a table of atomic weights corrected and fixed by various chemists in recent times:—

Denomination of the Substances.	Symbols.	Equivalents.		Atomic Weights.	
		O=100.	H=1.	O=100.	H=1.
Calcium (Erdmann and Marchand)	Ca.	250·000	20·000	250·000	40·000
Carbon (ditto)	C.	75·000	6·000	75·000	12·000
Hydrogen	H.	12·000	1·000	6·250	1·000
Iron (Erdmann and Marchand)	Fe.	350·000	23·000	250·100	56·000
Mercury (ditto)	Hg.	1250·000	100·000	1250·000	200·000
Phosphorus (Pelouze)	P.	400·000	32·024	200·150	32·024
Sodium (ditto)	Na.	287·170	22·973	287·170	45·046
Strontium (ditto)	Sr.	548·020	43·841	548·020	87·682
Sulphur (Erdmann and Marchand)	S.	200·000	16 000	200·000	32·000

Within the last few years the following atomic weights have been revised:—

Barium	Ba.	856·770	Marignac.
Calcium	Ca.	350.000	Erdm. and March.
Chromium	Cr.	333·500	Lefort.
Chromium	Cr.	335·091	Moberg.
Fluorine	Fl.	237·500	Louyet.
Magnesium	Mg.	152·550	Jacquelain.
Magnesium	Mg.	154·490	Svanberg.
Magnesium	Mg.	150.000	March. and Scheer.
Molybdenum	Mo.	574·750	Berlin.
Molybdenum	Mo.	574·829	Svanb. and Struve.
Tungsten	W.	1150·780	Schneider.

ELEMI is a resin which exudes from incisions made during dry weather through the bark of the *amyris elemifera*, a tree which grows in South America and Brazil. It comes to us in yellow, tender, transparent lumps, which readily soften by the heat of the hand. They have a strong aromatic odor, a hot spicy taste, and contain 12½ per cent. of etherous oil. The crystalline resin of elemi has been called *Elémine.* It is used in making lacquer, to give toughness to the varnish.

ELUTRIATE. (*Soutirer*, Fr.; *Schlemmen*, Germ.) When an insoluble pulverulent matter, like whitening or ground flints, is diffused through a large body of water, and the mixture is allowed to settle for a little, the larger particles will subside. If the supernatant liquid be now carefully decanted, or run off, with a syphon, it will contain an impalpable powder, which on repose will collect at the bottom, and may be taken out to dry. This process is called elutriation.

ELVAN. The name given by the Cornish miners to porphyry, as also to the heterogeneous rocky masses which occur in the granite or in the clay slate, deranging the direction of their metallic veins, or even the mineral strata; but elvan generally indicates a felspar porphyry.

EMBALMING. (*Embaument*, Fr.; *Einbalsamen*, Germ.) Is an operation in which balsams (*baumes*, Fr.) were employed to preserve human corpses from putrefaction; whence the name.

The ancient Egyptians had recourse to this process for preserving the bodies of numerous families, and even of the animals which they loved or worshipped. An excellent account of their methods is given in Mr. Pettigrew's work upon Mummies. Modern chemistry has made us acquainted with many means of counteracting putre-

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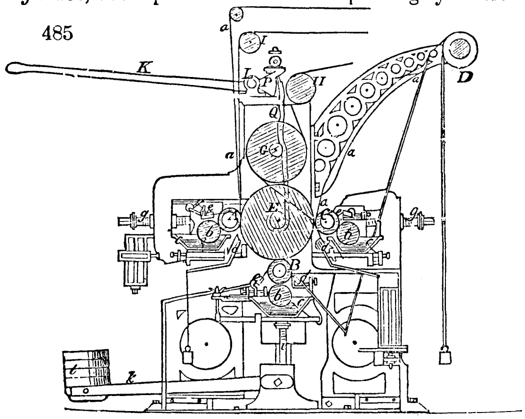
faction more simple and efficacious than the Egyptian system of salting, smoking, spicing, and bitumenizing. See PUTREFACTION.

EMBOSSING CLOTH. Mr. Thomas Greig, of Rose Bank, near Bury, patented an invention, in November, 1835, which consists in an ingenious construction of machinery for both embossing and printing silk, cotton, woollen cloth, paper, and other fabrics, in one or more colors, at one operation.

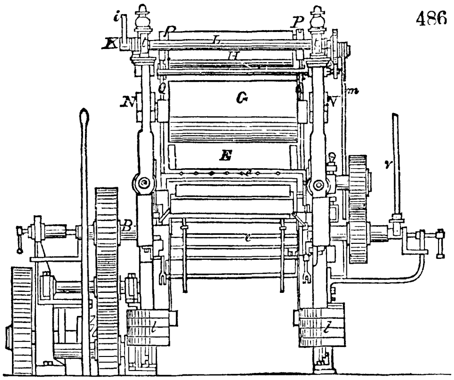
Figs. 485, 486 represent three distinct printing cylinders of copper, or other suitable material, A, B, C, with their necessary appendanges for printing three different colors upon the fabric as it passes through the machine either of these cylinders A, B, or C, may be employed as an embossing cylinder, without performing the printing process, or may be made to effect both operations at the same time.

485



The fabric or goods to be operated upon being first wound tightly upon a roller, that roller is to be mounted upon an axle or pivot, bearing in arms or brackets at the back of the machine, as shown at D. From this roller the fabric *a a a a* is conducted between tension rails, and passed under the bed cylinder or paper bowl E, and from thence proceeds over a carrier roller F, and over steam boxes not shown in the drawing, or it may be conducted into a hot room, for the purpose of drying the colors.

486



The cylinders A, B, and C, having neither engraved or raised surfaces, are connected to feeding rollers *b b b*, revolving in the ink or colored troughs *c c c;* or endless felts, called sieves, may be employed, as in ordinary printing machines, for supplying the color, when the device on the surface of the cylinders is raised: these cylinders may be furnished with doctors or scrapers when required, or the same may be applied to the endless felts.

The blocks have adjustable screws *g g*, for the purpose of bringing the cylinders up against the paper bowl, with any required degree of pressure: the cylinder B is supported by its gudgeons running in blocks, which blocks slide in the lower parts of the side frames, and are connected to perpendicular rods *i*, having adjustable screw nuts.

The lower parts of these rods bear upon weighted levers *k k*, extending in front of the machine; and by increasing the weights *l l*, any degree of upward pressure may be given to the cylinder B.

The color boxes or troughs *c c c*, carrying the feeding rollers *b b b*, are fixed on boards which slide in grooves in the side frames, and the rollers are adjusted and brought into contact with the surface of the printing cylinders by screws.

If a back cloth should be required to be introduced between the cylindrical bed or paper bowl E, and the fabric *a a a*, as the ordinary felt or blanket, it may, for printing and embossing cotton, silk, or paper, be of linen or cotton; but if woollen goods are to be operated upon, a cap of felt, or some such material, must be bound round the paper

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bowl, and the felt or blanket must be used for the black cloth, which is to be conducted over the rollers H and I.

For the purpose of embossing the fabric, either of the rollers A, B, or C, may be employed, observing that the surface of the roller must be cut, so as to leave the pattern or device elevated for embossing velvets, plain cloths, and papers; but for woollens the device must be excavated, that is, cut in recess.

The pattern of the embossing cylinder will, by the operation, be partially marked through the fabric on to the surface of the paper bowl E; to obliterate which marks from the surface of the bowl, as it revolves, the iron cylinder roller G is employed; but as in the embossing of the same patterns on paper, a counter roller is required to produce the pattern perfectly, the iron roller is in that case dispensed with, the impression given to the paper bowl being required to be retained on its surface until the operation is finished.

In this case the relative circumferences of the embossing cylinder, and of the paper bowl, must be exactly proportioned to each other; that is, the circumference of the bowl must be equal, exactly, to a given number of circumferences of the embossing cylinder, very accurately measured, in order to preserve a perfect register or coincidence, as they continue revolving between the pattern on the surface of the embossing cylinder, and that indented into the surface of the paper bowl.

The axle of the paper bowl E, turns in brasses fitted into slots in the side frames, and it may be raised by hand from its bearings when required, by a lever *k*, extending in front. This lever is affixed to the end of a horizontal shaft L, L, crossing the machine seen in the figures, at the back of which shaft there are two segment levers P, P, to which bent rods Q, Q, are attached, having hooks at their lower ends, passed under the axle of the bowl. At the reverse end of the shaft L, a ratchet-wheel *r*, is affixed, and a pall or click mounted on the side of the frame takes into the teeth of the wheel *r*, and thereby holds up the paper bowl when required.

When the iron roller G, is to be brought into operation, the vertical screws *t*, *t*, mounted in the upper parts of the side frames, are turned, in order to bring down the brasses N, which carry the axle of that roller and slide in slots in the side frames.

The cylinders A, B, and C, are represented hollow, and may be kept at any desired temperature during the operation of printing, by introducing steam into them; and under the color boxes *c*, *c*, *c*, hollow chambers are also made for the same purpose. The degree of temperature required to be given to these must depend upon the nature of the coloring material, and of the goods operated upon. For the purpose of conducting steam to these hollow cylinders and color boxes, pipes, as shown at *v*, *v*, *v*, are attached, which lead from a steam boiler. But when either of these cylinders is employed for embossing alone, or for embossing and printing at the same time, and particularly for some kinds of goods where a higher temperature may be required, a red-hot heater is then introduced into the hollow cylinder in place of steam.

If the cylinder B is employed as the embossing cylinder, and it is not intended to print the fabric by that cylinder simultaneously with the operation of embossing, the feeding roller *b*, must be removed, and also the color box *c*, belonging to that cylinder; and the cylinders A and C, are to be employed for printing the fabric, the one applying the color before the embossing is effected, the other after it. It is however to be remarked, that if A, and C, are to print colors on the fabric, and B to emboss it, in that case it is preferred, where the pattern would allow it. A and C, are wooden rollers having the pattern upon their surfaces, and not metal, as the embossing cylinders must of necessity be.

It will be perceived that this machine will print one, two, or three colors at the same time, and that the operation of embossing may be performed simultaneously with the printing, by either of the cylinders A, B, or C, or the operation may be performed consecutively by the cylinders, either preceding or succeeding each other.

The situations of the doctors, when required to be used for removing any superfluous color from the surface of the printing cylinder, are shown at *d*, *d*, *d*; those for removing any lint which may attach itself, at *e*, *e*, *e*. They are kept in their bearings by weighted levers and screws, and receive a slight lateral movement to and fro, by means of the vertical rod *m*, which is connected at top to an eccentric, on the end of the axle of the roller E, and at its lower end to a horizontal rod mounted at the side of the frame; to this horizontal rod, arms are attached, which are connected to the respective doctors; and thus, by the rotation of the eccentric, the doctors are made to slide laterally.

When the cylinders A, B, or C, are employed for embossing only, those doctors will not be required. The driving power is communicated to the machine from any first mover through the agency of the toothed gear, which gives rotatory motion to the cylinder B, and from thence to the other cylinders A, and C, by toothed geer shown in *Fig.* 485.

EMBOSSING OF LEATHER. Beautiful ornaments in basso-relievo for decorating the exteriors or interiors of buildings, medallions, picture-frames, cabinet work,

&c., have been recently made by the pressure of metallic blocks and dies, for which invention a patent was obtained in June, 1839, by M. Claude Schroth. The dies are made of type metal, or of the fusible alloy with bismuth, called d'Arcet's. The leather is beaten soft in water, then wrung, pressed, rolled, and fulled as it were, by working it with the hands till it becomes thicker and quite supple. In this state it is laid on the mould, and forced into all its cavities by means of a wooden bone, or copper tool. In other cases, the embossing is performed by the force of a press. The leather, when it has become dry, is easily taken off the mould, however deeply it may be inserted into its crevices, by virtue of its elasticity. A full detail of all the processes is given in *Newton's Journal*, vol. xxii. p. 122.

EMBOSSING WOOD. (*Bossage*, Fr.; *Erhabenes, Arbeit*, Germ.) Raised figures upon wood, such as are employed in picture-frames and other articles of ornamental cabinet work, are usually produced by means of carving, or by casting the pattern in plaster of Paris, or other composition, and cementing, or otherwise fixing it on the surface of the wood. The former mode is expensive; the latter is inapplicable on many occasions. The invention of Mr. Streaker may be used either by itself, or in aid of carving; and depends on the fact, that if a depression be made by a blunt instrument on the surface of the wood, such depressed part will again rise to its original level by subsequent immersion in the water.

The wood to be ornamented having been first worked out to its proposed shape, is in a state to receive the drawing of the pattern; this being put on, a blunt steel tool, or burnisher, or die, is to be applied successively to all those parts of the pattern intended to be in relief, and, at the same time, is to be driven very cautiously, without breaking the grain of the wood, till the depth of the depression is equal to the intended prominence of the figures. The ground is then to be reduced by planing or filing to the level of the depressed part; after which, the piece of wood being placed in water, either hot or cold, the part previously depressed will rise to its former height, and will then form an embossed pattern, which may be finished by the usual operations of carving.

For this invention the Society of Arts voted to Mr. Streaker their silver Isis medal and ten guineas.

EMBROIDERING MACHINE. (*Machine à broder*, Fr.; *Steckmaschine*, Germ.) This art has been till of late merely a handicraft employment, cultivated on account of its elegance by ladies of rank. But a few years ago M. Heilmann, of Mulhause, invented a machine of a most ingenious kind, which enables a female to embroider any design with 80 or 100 needles as accurately and expeditiously as she formerly could do with one. A brief account of this remarkable invention will therefore be acceptable to many readers. It was displayed at the national exposition of the products of industry in Paris for 1834, and was unquestionably the object which stood highest in public esteem; for whether at rest or in motion, it was always surrounded with a crowd of curious visiters, admiring the figures which it had formed, or inspecting its movements and investigating its mechanism. 130 needles were occupied in copying the same pattern with perfect regularity, all set in motion by one person.

Several of these machines are now mounted in France, Germany, and Switzerland. I have seen one factory in Manchester, where a great many of them are doing beautiful work.

The price of a machine having 130 needles, and of consequence 260 pincers or fingers and thumbs to lay hold of them, is 5000 francs, or 200*l.* sterling; and it is estimated to do daily the work of 15 expert hand embroiderers, employed upon the ordinary frame. It requires merely the labor of one grown-up person, and two assistant children. The operative must be well taught to use the machine, for he has many things to attend to; with the one hand he traces out, or rather follows the design with the point of the pantograph; with the other he turns a handle to plant and pull all the needles, which are seized by pincers and moved along by carriages, approaching to and receding from the web, rolling all the time along an iron railway; lastly, by means of two pedals, upon which he presses alternately with the one foot and the other, he opens the 130 pincers of the first carriage, which ought to give up the needles after planting them in the stuff, and he shuts with the same pressure the 130 pincers of the second carriage, which is to receive the needles, to draw them from the other side, and to bring them back again. The children have nothing else to do than to change the needles when all their threads are used, and to see that no needle misses its pincers.

This machine deserves particular attention, because it is no less remarkable for the happy arrangement of its parts, than for the effects which it produces. It may be described under four heads: 1. the structure of the frame; 2. the disposition of the web; 3. the arrangement of the carriages; and 4. the construction of the pincers.

1. The structure of the frame. It is composed of cast-iron, and is very massive. *Fig.* 487 exhibits a front elevation of it. The length of the machine depends upon he number of pincers to be worked. The model at the exposition had 260

pincers, and was 2 metres and a half (about 100 inches or 8 feet 4 inches English) long. The figure here given has been shortened considerably, but the other proportions are not disturbed. The breadth of the frame ought to be the same for every machine, whether it be long or short, for it is the breadth which determines the length of the thread to be put into the needles, and there is an advantage in giving it the full breadth of the model machine, fully 100 inches, so that the needles may carry a thread at least 40 inches long.

Disposition of the piece to be embroidered.—We have already stated that the pincers which hold the needles always present themselves opposite to the same point, and that in consequence they would continually pass backward and forward through the same hole, if the piece was not displaced with sufficient precision to bring successively opposite the tips of the needles every point upon which they are to work a design, such as a flower.

The piece is strained perpendicularly upon a large rectangular frame, whose four sides are visible in *fig*, 487; namely, the two vertical sides at F F, and the two horizontal sides, the upper and lower at F′ F″. We see also in the figures two long wooden rollers

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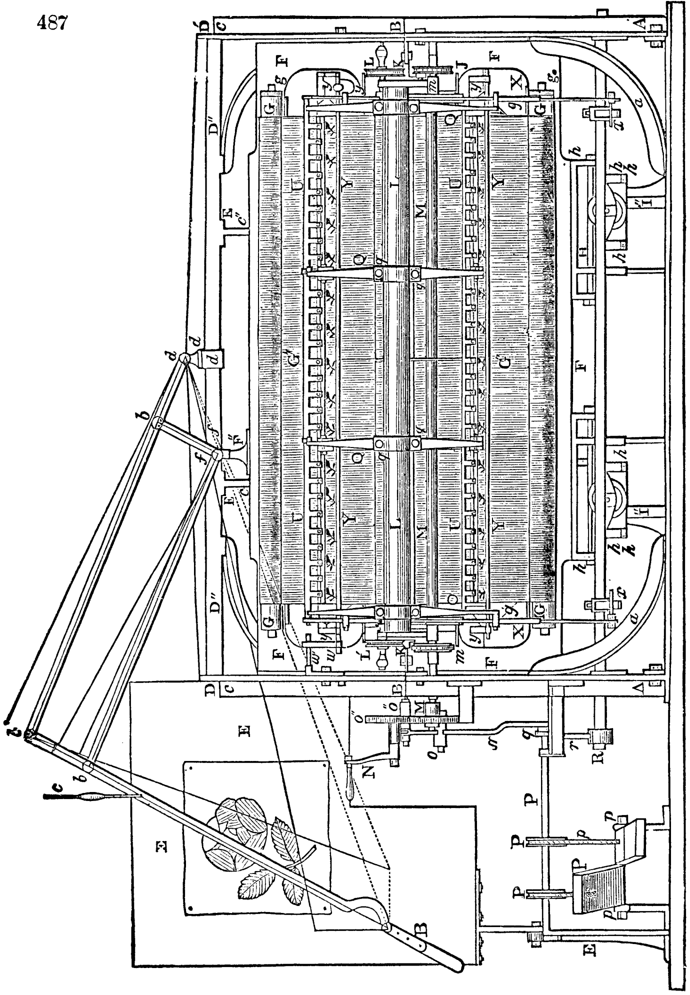

G and G, whose ends, mounted with iron studs, are supported upon the sides F of the frame, so as to turn freely, These form a system of beams upon which the piece destined to receive the embroidery, is wound and kept vertically stretched to a proper degree, for each of these beams bears upon its end a small ratchet wheel g, g; the teeth of one of them being inclined in the opposite direction to those of the other. Besides this system of lower beams, there is another of two upper beams, which is however but imperfectly seen in the figure, on account of the interference of other parts in this view of the machine. One of these systems presents the web to the inferior needles, and the other to the upper needles. As the two beams are not in the same vertical plane, the plane of the web would be presented obliquely to the needles were it not for a straight bar of iron, round whose edge the cloth passes, and which renders it vertical. The piece is kept in tension crosswise by small brass templets, to which the strings g'' are attached, and by which it is pulled toward the sides of the frame F. It remains to show by what ingenious means this frame may be shifted in every possible direction. M. Heilmann has employed for this purpose the pantograph which draughtsmen use for reducing or enlarging their plans in determinate proportions.

$b\,b'\,f'\,b''$ (*fig.* 487) represents a parallelogram of which the four angles b, b', f', b'' are jointed in such a way that they may become very acute or very obtuse at pleasure, while the sides of course continue of the same length; the sides $b\,b'$ and $b\,b''$ are prolonged, the one to the point d, and the other to the point c, and these points c and d are chosen under the condition that in one of the positions of the parallelogram, the line $c\,d$ which joins them passes through the point f; this condition may be fulfilled in an infinite number of manners, since the position of the parallelogram remaining the same, we see that if we wished to shift the point d further from the point b', it would be sufficient to bring the point c near enough to b'', or *vice versâ;* but when we have once fixed upon the distance $b'\,d$, it is evident that the distance $b''\,c$ is its necessary consequence. Now the principle upon which the construction of the pantograph rests is this; it is sufficient that the three points d, f, and c be in a straight line, in one only of the positions of the parallelogram, in order that they shall remain always in a straight line in every position which can possibly be given to it.

We see in the figure that the side $b\,c$ has a handle B$''$ with which the workman puts the machine in action. To obtain more precision and solidity in work, the sides of the pantograph are joined, so that the middle of their thickness lies exactly in the vertical plane of the piece of goods, and that the axes of the joints are truly perpendicular to this plane, in which consequently all the displacements are effected. We arrive at this result by making fast to the superior great cross bar D$''$ an elbow piece d'', having a suitable projection, and to which is adapted in its turn the piece d', which receives in a socket the extremity of the side b, a; this piece d' is made fast to d'' by a bolt, but it carries an oblong hole, and before screwing up the nut, we make the piece advance or recede, till the fulcrum point comes exactly into the plane of the web. This condition being fulfilled, we have merely to attach the frame to the angle f of the parallelogram, which is done by means of the piece F$''$.

It is now obvious that if the embroiderer takes the handle B$''$ in his hand and makes the pantograph move in any direction whatever, the point f will describe a figure similar to the figure described by the point c, and six times smaller, but the point f cannot move without the frame, and whatever is upon it moving also. Thus, in the movement of the pantograph, every point of the web describes a figure equal to that described by the point f, and consequently similar to that described by the point c, but six times smaller; the embroidered object being produced upon the cloth in the position of that of the pattern. It is sufficient therefore to give the embroidering operative who holds the handle B$''$, a design six times greater than that to be executed by the machine, and to afford him at the same time a sure and easy means of tracing over with the point c, all the outlines of the pattern. For this purpose he adapts to c, perpendicularly to the plane of the parallelogram, a small style terminated by a point C$'$, and he fixes the pattern upon a vertical tablet E, parallel to the plane of the stuff and the parallelogram, and distant from it only by the length of the style c C$''$; this tablet is carried by the iron rod e', which is secured to a cast iron foot E$'$, serving also for other purposes, as we shall presently see. The frame loaded with its beams and its cloth forms a pretty heavy mass, and as it must not swerve from its plane, it needs to be lightened in order that the operative may cause the point of the pantograph to pass along the tablet without straining or uncertainty in its movements. M. Heilmann has accomplished these objects in the following way. A cord e attached to the side $b\,c$ of the pantograph passes over a return pulley, and carries at its extremity, a weight which may be graduated at pleasure; this weight equipoises the pantograph, and tends slightly to raise the frame. The lower side of the frame carries two rods H and H, each attached by two arms $h\,h$, a little bent to the left; both of these are engaged in the grooves of a pulley. Through this mechanism a pressure can be exercised upon the frame from below upwards, which may be regulated at pleasure, and without preventing the frame from moving in all directions, it hinders it from deviating from the primitive plane to which the pantograph was adjusted. The length of the rods H ought to be equal to the amount of the lateral movement of the frame. Two guides *i i* carried by two legs of cast iron, present vertical slits in which the lower part of the frame F′ is engaged.

Disposition of the carriages.—The two carriages, which are similar, are placed the one to the right, and the other to the left of the frame. The carriage itself is composed merely of a long hollow cylinder of cast iron L, carrying at either end a system of two grooved castors or pulleys L′, which roll upon the horizontal rails K; the pulleys are mounted upon a forked piece *l′*, with two ends to receive the axes of the pulleys, and the piece *l′* is itself bolted to a projecting ear *l* cast upon the cylinder.

This assemblage constitutes properly speaking the carriage, resting in a perfectly stable equilibrium upon the rails K, upon which it may be most easily moved backwards and forwards, carrying its train of needles to be passed or drawn through the cloth.

M. Heilmann has contrived a mechanism by which the operative without budging from his place may conduct the carriages, and regulate as he pleases the extent of their course, as well as the rapidity of their movements. By turning the axes M″ in the one direction or the other, the carriage may be made to approach to, or recede from the web.

When one of the carriages has advanced to prick the needles into the stuff, the other is there to receive them; it lays hold of them with its pincers, pulls them through, performs its course by withdrawing to stretch the thread, and close the stitch, then it goes back with the needles to make its pricks in return. During these movements the first carriage remains at its post waiting the return of the second. Thus the two chariots make in succession an advance and a return, but they never move together.

To effect these movements M. Heilmann has attached to the piece O′ made fast to the two uprights A C and A D of the frame, a bent lever *n o n′ n″* moveable round the point *o;* the bend *n′* carries a toothed wheel O′, and the extremity *n″* a toothed wheel O″; the four wheels M M′ O′ and O″ have the same number of teeth and the same diameter; the two wheels O′ and O″ are fixed in reference to each other, so that it is sufficient to turn the handle N to make the wheel O″ revolve, and consequently the wheel O′; when the lever *n o* is vertical, the wheel O′ touches neither the wheel M nor the wheel M′; but if it be inclined to the one side or the other, it brings the wheel O′ alternately into gear with the wheel M or the wheel M′. As the operative has his two hands occupied, the one with the pantograph and the other with the handle of impulsion, he has merely his feet for acting upon the lever *n o*, and as he has many other things to do, M. Heilmann has adapted before him a system of two pedals, by which he executes with his feet a series of operations no less delicate than those which he executes with his hands.

The pedals P are moveable round the axis *p*, and carry cords *p′* wound in an opposite direction upon the pulleys P′; these pulleys are fixed upon a moveable shaft P″, supported upon one side by the prop E′, and on the other in a piece K′ attached to the two great uprights of the frame. In depressing the pedal P (now raised in the figure), the upper part of the shaft P″ will turn from the left to the right, and the lever *n o* will become inclined so as to carry the wheel O′ upon the wheel M′, but at the same time the pedal which is now depressed will be raised, because its cord will be forced to wind itself upon its pulley, as much as the other cord has unwound itself; and thus the apparatus will be ready to act in the opposite direction, when wanted.

Disposition of the pincers.—The shaft L′ carries, at regular intervals of a semi-diameter, the appendages *q q* cast upon it, upon which are fixed, by two bolts, the curved branches Q destined to bear the whole mechanism of the pincers. When the pincers are opened by their appropriate leverage, and the half of the needle, which is pointed at each end, with the eye in the middle, enters the opening of its plate, it gets lodged in an angular groove, which is less deep than the needle is thick, so that when the pincers are closed, the upper jaw presses it into the groove. In this way the needle is firmly held, although touched in only three points of its circumference.

Suppose, now, that all the pincers are mounted and adjusted at their proper distances upon their prismatic bar, forming the upper range of the right carriage. For opening all the pincers there is a long plate of iron, U, capable of turning upon its axis, and which extends from the one end of the carriage to the other. This axis is carried by a kind of forks which are bolted to the extremity of the branches Q. By turning that axis the workman can open the pincers at pleasure, and they are again closed by springs. This movement is performed by his feet acting upon the pedals.

The threads get stretched in proportion as the carriage is run out, but as this tension has no elastic play, inconveniences might ensue which are prevented by adapting to the carriage a mechanism by means of which all the threads are pressed at the same time by a weight susceptible of graduation. A little beneath the prismatic bar, which carries the pincers, we see in the figure a shaft, Y, going from one end of the carriage to the other, and even a little beyond it; this shaft is carried by pieces *y* which are fixed to the arms Q, and in which it can turn. At its left end it carries two small bars *y′* and *w′*, and at its right a single bar *y′*, and a counterweight (not visible in this view); the ends of the two bars *y′* are joined by an iron wire somewhat stout and perfectly straight. When the carriage approaches the web, and before the iron wire can touch it, the little bar *w* presses against a pin, *w′*, which rests upon it, and tends to raise it more and more. In what has preceded we have kept in view only the upper range of pincers and needles, but there is an inferior range quite similar, as the figure shows, at the lower ends of the arms Q. In conclusion, it should be stated, that the operative does not follow slidingly with the pantograph the trace of the design which is upon the tablet or the picture, but he must stop the point of the style upon the point of the pattern into which the needle should enter, then remove it, and put it down again upon the point by which the needle ought to re-enter in coming from the other side of the piece, and so on in succession. To facilitate this kind of reading off, the pattern upon the tablet is composed of right lines terminated by the points for the entrance and return of the needle, so that the operative (usually a child) has continually under her eyes the series of broken lines which must be followed by the pantograph; if she happens to quit this path an instant, without having left a mark of the point at which she had arrived, she is under the necessity of looking at the piece to see what has been already embroidered, and to find by this comparison the point at which she must resume her work, so as not to leave a blank, or to repeat the same stitch.

Explanation of figure.

A, lower cross bars, which unite the legs of the two ends of the frame.
a, the six feet of the front end of the frame.
a′, the six feet of the posterior end of the frame.
a″, curved pieces which unite the cross bars A″ to the uprights.
B″, handle of the pantograph.
b b′ b″, three of the angles of the pantograph.
c, point of the side *b b″* on which the point is fixed.
C″, point of the pantograph.
D″, cross bar in form of a gutter, which unites the upper parts of the frame.
d, fixed point, round which the pantograph turns.
E, tablet upon which the pattern to be embroidered is put.
E′, support of that tablet.
e, cord attached at one end to the side *b c* of the pantograph passing over a guide pulley, and carrying a weight at the other end.
e′, iron rod by which the tablet E is joined to its support E′.
F, F, uprights of the cloth-carrying frame.
F′, F′, horizontal sides of the same frame.
G, four roll beams.
G″, the piece of cloth.
g″, the strings, which serve to stretch the cloth laterally.

EMERALD (*Emeraude*, Fr.; *Smaragd*, Germ.), is a precious stone of a beautiful green color; valued next to diamond, and in the same rank as oriental ruby and sapphire. It occurs in prisms with a regular hexagonal base; sp. grav. 2·7; scratches quartz with difficulty; is scratched by topaz; fusible at the blowpipe into a frothy bead; the precipitate afforded by ammonia, from its solution, is soluble, in a great measure, in carbonate of ammonia. Its analysis is given very variously by different chemists. It contains about 14 per cent. of glucina, which is its characteristic constituent; along with 68 of silica, 16 of alumina, a very little lime and iron. The beautiful emerald of Peru is found in a clay schist mixed with some calcareous matter. A stone of 4 grains weight is said to be worth from 4*l.* to 5*l.*; one of 8 grains, 10*l.*; one of 15 grains, being fine, is worth 60*l*; one of 24 grains fetched, at the sale of M. de Drée's cabinet, 2400 francs, or nearly 100*l.*

The beryl is analogous in composition to the emerald, and is employed (when of the common opaque kind, found near Limoges), by chemists, for procuring the earth glucina.

EMERY. This mineral was long regarded as an ore of iron; and was called by Haüy *fer oxidé quartzifère*. It is very abundant in the island of Naxos, at cape *Emeri*, whence it is imported in large quantities. It occurs also in the islands of Jersey and Guernsey, at Almaden, in Poland, Saxony, Sweden, Persia, &c. Its color varies from red brown to dark brown; its specific gravity is about 4·000; it is so hard as to scratch quartz and many precious stones. By Mr. Tenant's analysis, it consists of alumina, 80; silica, 3; iron, 4. Another inferior kind yielded 32 of iron, and only 50 of alumina.

We have recent accounts of emery discoveries in Minesota, but nearly all that is used at present in the arts comes from Turkey, near ancient Smyrna. Dr. Lawrence Smith, the American geologist, made a discovery of a deposit of emery while residing in Smyrna, and he made an examination of the locality in 1847.

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Dr. Smith having reported his discoveries to the Turkish government, a commission of inquiry was instituted, and the business soon assumed a mercantile form. The monopoly of the emery of Turkey was sold to a mercantile house in Smyrna, and since then the price has diminished in the market.

The mining of the emery is of the simplest character. The natural decomposition of the rock in which it occurs facilitates its extraction. The rock decomposes into an earth, in which the emery is found imbedded. The quantity procured under these circumstances is so great that it is rarely necessary to explore the rock. The earth in the neighborhood of the block is almost always of a red color, and serves as an indication to those who are in search of the mineral. Sometimes, before beginning to excavate, the spots are sounded by an iron rod with a steel point, and when any resistance is met with, the rod is rubbed in contact with the resisting body, and the effect produced on the point enables a practised eye to decide whether it has been done by emery or not. The blocks which are of a convenient size are transported in their natural state, but are frequently broken by large hammers; when they resist the action of the hammer, they are subjected to the action of fire for several hours, and on cooling they most commonly yield to blows. It sometimes happens that large masses are abandoned, from the impossibility of breaking them into pieces of a convenient size, as the transportation, either on camels or horses, requires that pieces shall not exceed 100 lbs. each in weight.

Emery appears to be a mechanical mixture of corundum and oxide of iron.

When reduced to a powder, it varies in color from dark grey to black. The color of its powder affords no indication of its commercial value. The powder examined under the microscope shows the distinct existence of two minerals, corundum and oxide of iron. Emery, when moistened, always affords a very strong argillaceous odor. Its hardness is its most important property in its application to the arts, and was ascertained by Mr. Smith in the following manner:—Fragments were broken from the piece to be examined, and crushed in a diamond mortar with two or three blows of a hammer, then thrown into a sieve with 400 holes to the inch. The powder is then weighed, and the hardness tested with a circular piece of glass, about four inches in diameter, and a small agate mortar. The glass is first weighed, and placed on a piece of glazed paper; the pulverized emery is then thrown upon it at intervals, rubbing it against the glass with the bottom of the agate mortar. The emery is brushed off the glass from time to time with a feather, and when all the emery has been made to pass once over the glass, it was collected, and passed through the same operation three or four times. The glass was then weighed, again subjected to the same operation, the emery by this time being reduced to an impalpable powder. This series of operations is continued until the loss sustained by the glass is exceedingly small. The total loss in the glass is then noted, and when all the specimens of emery are submitted to this operation under the same circumstances, an exact idea of their relative hardness is obtained. The advantages of using glass and agate are, that the latter is sufficiently hard to crush the emery, and in a certain space of time to reduce it to such an impalpable state, that it has no longer any sensible effect on the glass; and, on the other hand, the glass is soft enough to lose during this time sufficient of its substance to allow of accurate comparative results. By this method, the best emery was found capable of wearing away about half of its weight of common French window-glass. The blue sapphire of Ceylon, pulverized and experimented with in this manner, wears away more than four-fifths of its weight. This furnished the standard of comparison.

In the ordinary process, the lumps of emery ore are broken up in the same manner as stone is for repairing Macadamised roads, and into lumps of similar size. These lumps then crushed under stampers, such as are used for pounding metallic ores, driven by water or by steam power. It is supposed that the stampers leave the fragments more angular than they would be if they were ground under runners, a mode which is sometimes employed. The coarse powder is then sifted through sieves of wire cloth, which are generally cylindrical, like the bolting cylinders of corn-mills; but the sieves are covered with wire cloth, having in general about ninety to sixteen wires to the inch. No. 16 sieve gives emery of about the size of mustard-seed; and coarser fragments, extending nearly to the size of pepper-corns, are also occasionally prepared for the use of engineers. The sieves have sometimes as many as 120 wires to the inch; but the very fine sizes of emery are more commonly sifted through lawn sieves. The finest emery that is obtained from the manufacturers is that which floats in the atmosphere of the stamping-room, and is deposited on the beams and shelves, from which it is occasionally collected. The manufacturers rarely or never wash the emery; this is mostly done by the glass-workers, and such others as require a greater degree of precision than can be obtained by sifting.

Washing emery by hand is far too tedious for those who require very large quantities of emery, such as the manufacturers of plate-glass and some others who generally adopt the following method:—Twelve or more cylinders of sheet copper, of the common height of about two feet, and varying from about three, five, eight, to thirty or forty inches in diameter, are placed exactly level, and communicating at their upper edges, each to the next, by small troughs or channels; the largest vessel has also a waste-pipe near the top. At the commencement of the process, the cylinders are all filled to the brim with clean water; the pulverised emery is then churned up with abundance of water in another vessel, and allowed to run into the smallest or three-inch cylinder, through a tube opposite the gutter leading to the second cylinder. The water during its short passage across the three-inch cylinder, deposits in that vessel such of the coarsest emery as will not bear suspension for that limited time; the particles next finer are deposited in the five-inch cylinder, during the somewhat longer time the mixed steam takes in passing the brim of that vessel; and so on. Eventually the water forms a very languid eddy in the largest cylinder, and deposits therein the very fine particles that have remained in suspension until this period; and the water, lastly, escapes by the waste-pipe nearly or entirely free from emery. In this simple arrangement, time is also the measure of the particles respectively deposited in the manufacture to which the emery is applied. When the vessels are to a certain degree filled with emery, the process is stopped, the vessels are emptied, the emery is carefully dried and laid by, and the process is recommenced.

Emery paper is prepared by brushing the paper over with thin glue, and dusting the emery-powder over it from a sieve. There are about six degrees of coarseness. Sieves with thirty and ninety meshes per linear inch, are in general the coarsest and finest sizes employed. When used by artizans, the emery-paper is commonly wrapped around a file or a slip of wood, and applied just like a file, with or without oil, according to circumstances. The emery-paper cuts more smoothly with oil, but leaves the work dull.

Emery cloth only differs from emery-paper in the use of thin cotton cloth instead of paper, as the material upon which the emery is fixed by means of glue. The emery cloth, when folded around a file, does not ply so readily to it as emery-paper, and is apt to unroll. Hence smiths, engineers, and others, prefer emery-paper and emery-sticks; but for household and other purposes, where the hand alone is used, the greater durability of the cloth is advantageous.

Emery-sticks are rods of board about eight or twelve inches long, planed up square; or with one side rounded like a half-round file. Nails are driven into each end of the stick as temporary handles; they are then brushed over one at a time with thin glue, and dabbed at all parts in a heap of emery-powder, and knocked on one end to shake off the excess. Two coats of glue and emery are generally used. The emery-sticks are much more economical than emery-paper wrapped on a file, which is liable to be torn.

Emery-cake consists of emery mixed with a little beeswax, so as to constitute a solid lump, with which to dress the edges of buff and glaze wheels. The ingredients should be thoroughly incorporated by stirring the mixture whilst fluid, after which it is frequently poured into water, and thoroughly kneaded with the hands, and rolled into lumps before it has time to cool. The emery-cake is sometimes applied to the wheels whilst they are revolving; but the more usual course is, to stop the wheel, and rub in the emery-cake by hand. It is afterwards smoothed down by the thumb.

Emery-paper, or patent razor-strop paper, an article in which fine emery and glass are mixed with paper pulp, and made into sheets as in making ordinary paper; the emery and glass are said to constitute together 60 per cent. of the weight of the paper, which resembles drawing-paper, except that it has a delicate fawn color. The emery-paper is directed to be pasted or glued upon a piece of wood, and when rubbed with a little oil, to be used as a razor-strop.

In 1842, Mr. Henry Barclay took out a patent for a method of combining powdered emery into *discs* and *laps* of different kinds, suitable to grinding, cutting, and polishing glass, enamels, metals, and other hard substances. The process of manufacture is as follows:—Coarse emery-powder is mixed with about half its weight of pulverized Stourbridge loam and a little water or other liquid, to make a thick paste; this is pressed into a metallic mould by means of a screw-press, and after having been thoroughly dried, is baked or burned in a muffle or close receiver at a temperature considerably above a red heat, and below the full white heat. In this case, the clay or alumina serves as a bond, and unites the particles very completely into a solid artificial emery-stone, which cuts very greedily, and yet seems hardly to suffer perceptible wear.

Superfine grinding emery is formed into wheels exactly in the same manner as the above, but the proportion of loam is then only one-fourth instead of one-half that of the emery. Those emery stones, which are of medium fineness, cut less quickly, but more smoothly than the above.

Flour-emery, when manufactured into artificial stones, requires no uniting substance, but the moistened powder is forced into the metal mould and fired; some portions of the alumina being sufficient to unite the whole. These fine wheels render the works

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submitted to them exceedingly smooth, but they do not produce a high polish on account of the comparative coarseness of the flour-emery.

The alumina of emery is believed to be aggregated to the same degree of hardness as in corundum or adamantine spar; which is one of the hardest minerals known. Emery is extensively employed for grinding metals, glass, &c.; for which purpose it is reduced to powders of different degrees of fineness by grinding and elutriation.

2,000 tons per annum at from 50 to 70 dollars each, according to quality, are consumed in the United Kingdom.

EMPYREUMA, means the offensive smell produced by fire applied to organic matters, chiefly vegetable, in close vessels. Thus, empyreumatic vinegar is obtained by distilling wood at a red heat, and empyreumatic oil from many animal substances in the same way.

ENAMELS (*Emaux*, Fr.; *Schmelzglas*, Germ.) are varieties of glass, generally opaque and colored, always formed by the combination of different metallic oxydes, to which certain fixed fusible salts are added, such as the borates, fluates, and phosphates.

The simplest enamel, and the one which serves as a basis to most of the others, is obtained by calcining first of all a mixture of lead and tin, in proportions varying from 15 to 50 parts of tin for 100 of lead. The middle term appears to be the most suitable for the greater number of enamels; and this alloy has such an affinity for oxygen, that it may be calcined with the greatest ease in a flat cast-iron pot, and at a temperature not above a cherry red, provided the dose of tin is not too great. The oxyde is drawn off to the sides of the melted metal according as it is generated, new pieces of the alloy being thrown in from time to time, till enough of the powder be obtained. Great care ought to be taken that no metallic particles be left in the oxyde, and that the calcining heat be as low as is barely sufficient; for a strong fire frits the powder, and obstructs its subsequent comminution. The powder when cold is ground in a proper mill, levigated with water, and elutriated, as will be described under *Red lead.* In this state of fineness and purity, it is called calcine, or flux, and it is mixed with silicious sand and some alkaline matter or sea-salt. The most ordinary proportions are, 4 of sand, 1 of sea-salt, and 4 of *calcine.* Chaptal states that he has obtained a very fine product from 100 parts of calcine, made by calcining equal parts of lead and tin, 100 parts of ground flint, and 200 parts of pure subcarbonate of potash. In either case, the mixture is put into a crucible, or laid simply on a stratum of sand, quicklime spontaneously slaked, or wood-ashes, placed under a pottery or porcelain kiln. This mass undergoes a semi-vitrification; or even a complete fusion on its surface. It is this kind of frit which serves as a radical to almost every enamel; and by varying the proportions of the ingredient, more fusible, more opaque, or whiter enamels are obtained. The first of these qualities depends on the quantity of sand or flux, and the other two on that of the tin.

The sea-salt employed as a flux may be replaced either by salt of tartar, by pure potash, or by soda; but each of these fluxes gives peculiar qualities to the enamel.

Most authors who have written on the preparation of enamels, insist a great deal on the necessity of selecting carefully the particular sand that should enter into the composition of the frit, and they even affirm that the purest is not the most suitable. Clouet states, in the 34th volume of the *Annales de Chimie*, that the sand ought to contain at least 1 part of talc for 3 of silicious matter, otherwise the enamel obtained is never very glassy, and that some wrinkled spots from imperfect fusion are seeen on its surface; and yet we find prescribed in some old treatises, to make use of ground flints, fritted by means of salt of tartar or some other flux. It would thence appear that the presence of talc is of no use towards the fusibility of the silica, and that its absence may be supplied by increasing the dose of the flux. In all cases, however, we ought to beware of metallic oxydes in the sand, particularly those of iron and manganese, which most frequently occur, and always injure the whiteness of the frit.

The ancients carried the art of enamelling to a very high perfection, and we occasionally find beautiful specimens of their work, of which we know neither the composition, nor the manner of applying it. Then, as at present, each artist made a mystery of the means that succeeded best with him, and thus a multitude of curious processes have been buried with their authors. Another cause contributes powerfully to this sort of declension in the arts. Among the vast number of recipes which have been published for the formation of enamels, there are several in which substances are mentioned that can no longer be procured, whether owing to a change of denomination, or because the substances cannot now be found in commerce, or because they are not of the same nature as of old. Hence, in many cases, we find it impossible to obtain satisfactory results. What we have now said renders it desirable that the operations should be resumed anew, or upon new bases, and availing ourselves of all the known chemical facts, we should employ in the production of enamels, raw materials of the purest kind.

The Venetians are still in possession of the best enamel processes, and they supply the French and other nations with the best kinds of enamel, of every colored shade.

Enamels are distinguished into transparent and opaque; in the former all the elements have experienced an equal degree of liquefaction, and are thus run into crystal glass, whilst in the others, some of their elements have resisted the action of heat more, so that their particles retain sufficient aggregation to prevent the transmission of light. This effect is produced, particularly by the oxyde of tin, as we shall perceive in treating of white enamel.

The frits for enamels that are to be applied to metallic surfaces require greater fusibility, and should therefore contain more flux; and the sand used for these should be calcined beforehand with one fourth its weight of sea-salt; sometimes, indeed, metallic fluxes are added, as minium or litharge. For some metallic colors, the oxydes of lead are very injurious, and in this case recourse must be had to other fluxes. Clouet states that he had derived advantage from the following mixtures, as bases for purples, blues, and some other delicate colors:—

Three parts of silicious sand, one of chalk, and three of calcined borax; or, three of glass (of broken crystal goblets), one of calcined borax, one fourth of a part of nitre, and one part of well washed diaphoretic antimony. These compositions afford a very white enamel, which accords perfectly well with blue.

It is obvious that the composition of this primary matter may be greatly varied; but we should never lose sight of the essential quality of a good enamel; which is, to acquire, at a moderate heat, sufficient fluidity, to take a shining surface, without running too thin. It is not complete fusion which is wanted; but a pasty state, of such a degree as may give it, after cooling, the aspect of having suffered complete liquefaction.

Dead-white Enamel.—This requires greater nicety in the choice of its materials than any other enamel, as it must be free from every species of tint, and be perfectly white; hence the frit employed in this case should be itself composed of perfectly pure ingredients. But a frit should not be rejected hastily because it may be somewhat discolored, since this may depend on two causes; either on some metallic oxydes, or on fuliginous particles proceeding from vegetable or animal substances. Now the latter impurities may be easily removed by means of a small quantity of peroxyde of manganese, which has the property of readily parting with a portion of its oxygen, and of thus facilitating the combustion, that is to say, the destruction of the coloring carbonaceous matter. Manganese indeed possesses a coloring power itself on glass, but only in its highest state of oxydizement, and when reduced to the lower state, as is done by incombustible matters, it no longer communicates color to the enamel combinations. Hence the proportion of manganese should never exceed what is just; for the surplus would cause color. Sometimes, indeed, it becomes necessary to give a little manganese color, in order to obtain a more agreeable shade of white; as a little azure blue is added to linens, to brighten or counteract the dulness of their yellow tint.

A white enamel may be conveniently prepared also with a *calcine* composed of two parts of tin and one of lead calcined together; of this combined oxyde, one part is melted with two parts of fine crystal and a very little manganese, all previously ground together. When the fusion is complete, the vitreous matter is to be poured into clear water, and the frit is then dried, and melted anew. The pouring into water and fusion are sometimes repeated four times, in order to secure a very uniform combination. The crucible must be carefully screened from smoke and flame. The smallest portions of oxyde of iron or copper admitted into this enamel will destroy its value.

Some practitioners recommend the use of washed diaphoretic antimony (antimoniate of potash, from metallic antimony and nitre deflagrated together) for white enamel; but this product cannot be added to any preparation of lead or other metallic oxydes; for it would tend rather to tarnish the color than to clear it up; and it can be used therefore only with ordinary glass, or with saline fluxes. For three parts of white glass (without lead) one part of washed diaphoretic antimony is to be taken; the substances are well ground together, and fused in the common way.

Blue enamel.—This fine color is almost always obtained from the oxyde of cobalt or some of its combinations, and it produces it with such intensity that only a very little can be used, lest the shade should pass into black. The cobalt blue is so rich and lively that it predominates in some measure over every other color, and masks many so that they can hardly be perceived; it is also most easily obtained. To bring it out, however, in all its beauty, the other colors must be removed as much as possible, and the cobalt itself should be tolerably pure. This metal is associated in the best known ores with a considerable number of foreign substances, as iron, arsenic, copper, nickel, and sulphur, and it is difficult to separate them completely; but for enamel blues, the oxyde of cobalt does not require to be perfectly free from all foreign metals; the iron, nickel, and copper, being most prejudicial, should be carefully eliminated. This object may be most easily attained by dissolving the ore in nitric acid, evaporating the solution to a sirupy consistence, to expel the excess of acid, and separate a portion of arsenic. It is now diluted with water, and solution of carbonate of soda is dropped slowly into it with brisk agita tion, till the precipitate, which is at first of a whitish gray, begins to turn of a rose-red. Whenever this color appears, the whole must be thrown on a filter, and the liquid which passes through must be treated with more of the carbonate of soda, in order to obtain the arseniate of cobalt, which is nearly pure. Since arsenic acid and its derivatives are not capable of communicating color themselves, and as they moreover are volatile, they cannot impair the beauty of the blue, and hence this preparation affords it in great perfection.

Metallic fluxes are not the most suitable for this color; because they always communicate a tint of greater or less force, which never fails to injure the purity of the blue. Nitre is a useful addition, as it keeps the oxyde at the maximum of oxydation, in which state it produces the richest color.

Yellow Enamel.—There are many processes for making this color in enamel; but it is somewhat difficult to fix, and it is rarely obtained of a uniform and fine tint. It may be produced directly with some preparations of silver, as the phosphate or sulphate; but this method does not always succeed, for too strong a heat or powerful fluxes readily destroy it, and nitre is particularly prejudicial. This uncertainty of success with the salts of silver causes them to be seldom employed; and oxydes of lead and antimony are therefore preferred, which afford a fine yellow when combined with some oxydes that are refractory enough to prevent their complete vitrification. One part of white oxyde of antimony may be taken with from one to three parts of white lead, one of alum, and one of sal-ammoniac. Each of these substances is to be pulverized, and then all are to be exactly mixed, and exposed to a heat adequate to decompose the sal-ammoniac. This operation is judged to be finished when the yellow color is well brought out. There is produced here a combination quite analogous to that known under the name of Naples yellow.

Other shades of yellow may be procured either with the oxyde of lead alone, or by adding to it a little red oxyde of iron; the tints varying with the proportion of the latter.

Clouet says, in his memoir on enamels, that a fine yellow is obtained with pure oxyde of silver, and that it is merely necessary to spread a thin coat of it on the spot to be colored. The piece is then exposed to a moderate heat, and withdrawn as soon as this has reached the proper point. The thin film of metallic silver revived on the surface being removed, the place under it will be found tinged of a fine yellow, of hardly any thickness. As the pellicle of silver has to be removed which covers the color, it is requisite to avoid fixing this film with fluxes; and it ought therefore to be applied after the fusion of the rest. The yellows require in general little flux, and they answer better with one of a metallic nature.

Green Enamel.—It is known that a green color may be produced by a mixture of yellow and blue; but recourse is seldom had to this practice for enamels, as they can be obtained almost always directly with the oxyde of copper; or still better with the oxyde of chrome, which has the advantage of resisting a strong heat.

Chemists describe two oxydes of copper, the protoxyde, of an orange red color, which communicates its color to enamels, but it is difficult to fix; the deutoxyde is blue in the state of hydrate, but blackish-brown when dry, and it colors green all the vitreous combinations into which it enters. This oxyde requires, at most, one or two proportions of flux, either saline or metallic, to enter into complete fusion; but a much smaller dose is commonly taken, and a little oxyde of iron is introduced. To four pounds of frit, for instance, two ounces of oxyde of copper and 48 grains of red oxyde of iron are used; and the ordinary measures are pursued for making very homogeneous enamel.

The green produced by the oxyde of chrome is much more solid; it is not affected by a powerful fire, but it is not always of a fine shade. It generally inclines too much to the dead-leaf yellow, which depends on the degree of oxygenation of the chrome.

Red Enamel.—We have just stated that protoxyde of copper afforded a fine color when it could be fixed, a result difficult to obtain on account of the fugitive nature of this oxyde; slight variations of temperature enabling it to absorb more oxygen. The proper point of fusion must be seized, for taking it from the fire whenever the desired color is brought out. Indeed, when a high temperature has produced peroxydizement, this may be corrected by adding some combustible matter, as charcoal, tallow, tartar, &c. The copper then returns to its minimum of oxydizement, and the red color which had vanished, reappears. It is possible, in this way, and by pushing the heat a little, to accomplish the complete reduction of a part of the oxyde; and the particles of metallic copper thereby disseminated in a reddish ground, give this enamel the aspect of the stone called *avanturine.* The surest and easiest method of procuring protoxyde of copper is to boil a solution of equal parts of sugar, and sulphate or rather acetate of copper, in four parts of water. The sugar takes possession of a portion of the oxygen of the cupreous oxyde, and reduces it to the protoxyde; when it may be precipitated in the form of a granular powder of a brilliant red. After about two hours of moderate ebullition, the liquid is set aside to settle, decanted off the precipitate, which is washed and dried.

This pure oxyde, properly employed by itself, furnishes a red which vies with the fines carmine, and by its means every tint may be obtained from red to orange, by adding a greater or smaller quantity of peroxyde of iron.

The preparations of gold, and particularly the oxyde and purple of Cassius, are likewise employed, with advantage, to color enamel red, and this composition resists a powerful fire tolerably well. For some time back, solutions of gold, silver, and platinum have been used with success instead of their oxydes; and, in this way, a more intimate mixture may be procured, and, consequently, more homogeneous tints.

Black Enamel.—Black enamels are made with peroxyde of manganese or protoxyde of iron; to which more depth of color is given with a little cobalt. Clay alone, melted with about a third of its weight of protoxyde of iron, gives, according to Clouet, a fine black enamel.

Violet Enamel.—The peroxyde of manganese in small quantity by itself furnishes, with saline or alkaline fluxes, an enamel of a very fine violet hue; and variations of shade are easily had by modifying the proportions of the elements of the colored frit. The great point is to maintain the manganese in a state of peroxydation, and consequently to beware of placing the enamel in contact with any substance attractive of oxygen.

Such are the principal colored enamels hitherto obtained by means of metallic oxydes; but since the number of these oxydes is increasing every day, it is to be wished that new trials be made with such as have not yet been employed. From such researches some interesting results would unquestionably be derived.

Of painting on Enamel.—Enamelling is only done on gold and copper; for silver swells up, and causes blisters and holes in the coat of enamel. All enamel paintings are, in fact, done on copper or gold.

The goldsmith prepares the plate that is to be painted upon. The gold should be 22 carats fine: if purer, it would not be sufficiently stiff; if coarser, it would be subject to melt; and its alloy should be half white and half red, that is, half silver and half copper; whereby the enamel with which it is covered will be less disposed to turn green, than if the alloy were entirely copper.

The workman must reserve for the edge of the plate a small fillet, which he calls the *border*. This ledge serves to retain the enamel, and hinders it from falling off when applied and pressed on with a spatula. When the plate is not to be counter-enamelled, it should be charged with less enamel, as, when exposed to heat, the enamel draws up the gold to itself, and makes the piece convex. When the enamel is not to cover the whole plate, it becomes necessary to prepare a lodgment for it. With this view, all the outlines of the figure are traced on the plate with a black-lead pencil, after which recourse is had to the graver.

The whole space enclosed by the outlines must be hollowed out in *bas-relief*, of a depth equal to the height of the fillet, had the plate been entirely enamelled. This sinking of the surface must be done with a flat graver as equally as possible; for if there be an eminence, the enamel would be weaker at that point, and the green would appear. Some artists hatch the bottom of the hollow with close lines, which cross each other in all directions; and others make lines or scratches with the edges of a file broken off square. The hatchings or scratches lay hold off the enamel, which might otherwise separate from the plate. After this operation, the plate is cleansed by boiling it in an alkaline lye, and it is washed first with a little weak vinegar, and then with clear water.

The plate thus prepared is to be covered with a coat of white enamel, which is done by bruising a piece of enamel in an agate or porcelain mortar to a coarse powder like sand, washing it well with water, and applying it in the hollow part in its moist state.

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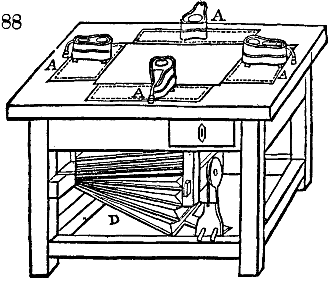

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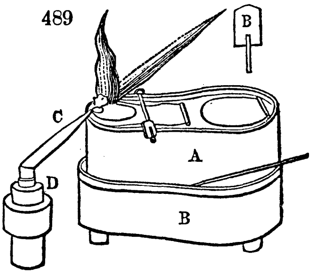

The plate may meanwhile be held in an ordinary forceps. The enamel powder is spread with a spatula. For condensing the enamel powder, the edges of the plate are struck upon with the spatula.

Whenever the piece is dry, it is placed on a slip of sheet iron perforated with several small holes, see *fig.* 490, which is laid on hot cinders; and it is left there until it ceases to steam. It must be kept hot till it goes to the fire; for were it allowed to cool it would become necessary to heat it again very gradually at the mouth of the furnace of fusion, to prevent the enamel from decrepitating and flying off.

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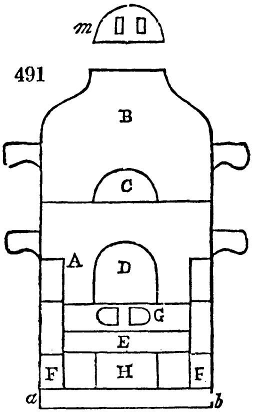

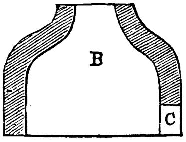

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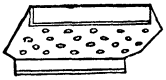

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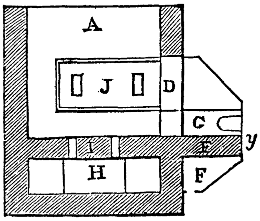

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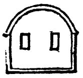

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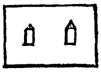

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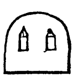

Before describing the manner of exposing the piece to the fire, we must explain the construction of the furnace. It is square, and is shown in front elevation in *fig.* 491. It consists of two pieces, the lower part A, or the body of the furnace, and the upper part B, or the capital, which is laid on the lower part, as is shown in *fig.* 492, where these two parts are separately represented. The furnace is made of good fire-clay, moderately baked, and resembles very closely the assay or cupellation furnace. Its inside dimensions are 9 inches in width; 13 inches in height in the body, and 9 in the capital. Its general thickness is 2 inches.

The capital has an aperture or door C, *fig.* 491, which is closed by a fire-brick stopper *m*, when the fire is to be made active. By this door fuel is supplied.

The body of the furnace has likewise a door D, which reaches down to the projecting shelf E, called the bib (*mentonnière*), whose prominence is seen at E, *fig.* 491. This shelf is supported and secured by the two brackets, F, F; the whole being earthenware.

The height of the door D, is abridged by a peculiar fire-brick G, which not only covers the whole projection of the shelf E, but enters within the opening of the door D, filling its breadth, and advancing into the same plane with the inner surface of the furnace. This plate is called the hearth; its purpose will appear presently; it may be taken out and replaced at pleasure, by laying hold of the handle in its front.

Below the shelf E, a square hole, H, is seen, which serves for admitting air, and for extracting the ashes. Similar holes are left upon each side of the surface, as is shown in the ground plan of the base, *fig.* 492, at H.

On a level with the shelf, in the interior of the furnace, a thin fire-tile I rests, perforated with numerous small holes. This is the grate represented in a ground view in *fig.* 490. *Figs.* 493, 494, 495, represent, under different aspects, the muffle. *Fig.* 492 shows the elevation of its further end; *fig.* 494, its sides; and *fig.* 495, its front part. At J, *fig.* 492, the muffle is seen in its place in the furnace, resting on two bars of iron, or, still better, on ledges of fire-clay, supported on brackets attached to the lateral sides of the furnace. The muffle is made of earthenware, and as thin as possible. The fuel consists of dry beech-wood, or oaken branches, about an inch in diameter, cut to the length of nine inches, in order to be laid in horizontal strata within the furnace, one row only being placed above the muffle. When the muffle has attained to a white red heat, the sheet iron tray, bearing its enamel plate, is to be introduced with a pair of pincers into the front of the muffle, and gradually advanced toward its further end. The mouth of the muffle is to be then closed with two pieces of charcoal only, between which the artist may see the progress of the operation. Whenever the enamel begins to flow, the tray must be turned round on its base to insure equality of temperature and as soon as the whole surface is melted, the tray must be withdrawn with its plate, but slowly, lest the vitreous matter be cracked by sudden refrigeration.

The enamel plate, when cold, is to be washed in very dilute nitric acid, and afterwards in cold water, and a second coat of granular enamel paste is to be applied, with the requisite precautions. This, being passed through the fire, is to be treated in the same way a third time, when the process will be found complete. Should any chinks happen to the enamel coat, they must be widened with a graver, and the space being filled with ground enamel, is to be repaired in the muffle. The plate, covered with a pure white enamel, requires always to be polished and smoothed with sandstone and water, particularly if the article have a plane surface; and it is then finally glazed at the fire.

The painting operation now follows. The artist prepares his enamel colors by pounding them in an agate mortar, with a pestle of agate, and grinding them on an agate slab, with oil of lavender, rendered viscid by exposure to the sun in a shallow vessel, loosely covered with gauze or glass. The grinding of two drachms of enamel pigment into an impalpable powder, will occupy a laborer a whole day. The painter should have alongside of him a stove in which a moderate fire is kept up, for drying his work whenever the figures are finished. It is then passed through the muffle.

Enamelling at the Lamp.—The art of the lamp enameller is one of the most agreeable and amusing that we know. There is hardly a subject in enamel which may not be executed by the lamp-flame in very little time, and more or less perfectly, according to the dexterity of the artist, and his acquaintance with the principles of modelling.

In working at the lamp, tubes and rods of glass and enamel must be provided, of all sizes and colors.

The enamelling table is represented in *fig.* 488, round which several workmen, with their lamps, may be placed, while the large double bellows D below is set a-blowing by a treadle moved with the foot. The flame of the lamp, when thus impelled by a powerful jet of air, acquires surprising intensity. The bent nozzles or tubes, A A A A, are made of glass, and are drawn to points modified to the purpose of the enameller.

Fig. 489 shows, in perspective, the lamp A of the enameller standing in its cistern B; the blowpipe C is seen projecting its flame obliquely upwards. The blowpipe is adjustable in an elastic cork D, which fills up exactly the hole of the table into which it enters. When only one person is to work at a table provided with several lamps, he sits down at the same side with the pedal of the bellows; he takes out the other blowpipes, and plugs the holes in the table with solid corks.

The lamp is made of copper or tin-plate, the wick of cotton threads, and either tallow or oil may be used. Between the lamp and the workman a small board or sheet of white iron B, called the screen, is interposed to protect his eyes from the glare of light. The screen is fastened to the table by a wooden stem, and it throws its shadow on his face.

The enamelling workshop ought to admit little or no daylight, otherwise the artist, not perceiving his flame distinctly, would be apt to commit mistakes.

It is impossible to describe all the manipulations of this ingenious art, over which taste and dexterity so entirely preside. But we may give an example. Suppose the enameller wishes to make a swan. He takes a tube of white enamel, seals one of its ends hermetically at his lamp, and while the matter is sufficiently hot, he blows on it a minikin flask, resembling the body of the bird; he draws out, and gracefully bends the neck; he shapes the head, the beak, and the tail; then, with slender enamel rods of a proper color, he makes the eyes; he next opens up the beak with pointed scissors; he forms the wings and the legs; finally attaching the toes, the bird stands complete.

The enameller also makes artificial eyes for human beings, imitating so perfectly the colors of the sound eye of any individual, as to render it difficult to discover that he has a blind and a seeing one.

It is difficult to make large articles at the blowpipe; those which surpass 5 or 6 inches become nearly unmanageable by the most expert workmen.

Enamelling of Cast Iron and other Hollow Ware for Saucepans, &c.—In December, 1799, a patent was obtained for this process by Dr. Samuel Sandy Hickling. His specification is subdivided into two parts:—

1. The coating or lining of iron vessels, &c., by fusion with a vitrifiable mixture, composed of 6 parts of calcined flints, 2 parts of *composition* or Cornish stone, 9 parts of litharge, 6 parts of borax, 1 part of argillaceous earth, 1 part of nitre, 6 parts of calx of tin, and 1 part of purified potash. Or, 2dly,

8 parts of calcined flints, 8 red lead, 6 borax, 5 calx of tin, and 1 of nitre. Or, 3dly,

12 of potter's composition, 8 borax, 10 white lead, 2 nitre, 1 white marble calcined, 1 argillaceous earth, 2 purified potash, and 5 of calx of tin. Or, 4thly,

4 parts calcined flint, 1 potter's composition, 2 nitre, 8 borax, 1 white marble calcined, ½ argillaceous earth, and 2 calx of tin.

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Whichever of the above compositions is taken, must be finely powdered, mixed, fused; the vitreous mass is to be ground when cold, sifted, and levigated with water. It is then made into a pap with water or gum-water. This pap is smeared or brushed over the interior of the vessel, dried, and fused with a proper heat in a muffle.

Calcined bones are also proposed as an ingredient of the flux.

The fusibility of the vitreous compounds is to vary according to the heat to be applied to the vessel, by using various proportions of the siliceous and fluxing materials. Colors may be given, and also gilding.

The second part or process in his specification describes certain alloys of iron and nickel, which he casts into vessels, and lines or coats them with copper precipitated from its saline solutions. It also describes a mode of giving the precipitated copper a brassy surface by acting upon it with an amalgum of zinc with the aid of heat.

A factory of such enamelled hollow wares was carried on for some time, but it was given up for want of due encouragement.

A patent was granted to Thomas and Charles Clarke on the 25th of May, 1839, for a method of enamelling or coating the internal surfaces of iron pots and saucepans, in such a way as shall prevent the enamel from cracking or splitting off from the effects of fire. The specification prescribes the vessel to be first cleansed by exposing it to the action of dilute sulphuric acid (sensibly sour to the taste) for three or four hours, then boiling the vessel in pure water for a short time, and next applying the composition. This consists of 100 lbs. of calcined ground flints; 50 lbs. of borax calcined, and finely ground with the above. That mixture is to be fused and gradually cooled.

40 lbs. weight of the above product is to be taken with 5 lbs. weight of potter's clay; to be ground together in water until the mixture forms a pasty-consistenced mass, which will leave or form a coat on the inner surface of the vessel about one sixth of an inch thick. When this coat is set, by placing the vessel in a warm room, the second composition is to be applied. This consists of 125 lbs. of white glass (without lead), 25 lbs. of borax, 20 lbs. of soda (crystals), all pulverized together and vitrified by fusion, then ground, cooled in water, and dried. To 45 lbs. of that mixture, 1 lb. of soda is to be added, the whole mixed together in hot water, and when dry, pounded; then sifted finely and evenly over the internal surface of the vessel previously covered with the first coating or composition, while this is still moist. This is the glazing. The vessel thus prepared is to be put into a stove, and dried at the temperature of 212° F. It is then heated in a kiln or muffle, like that used for glazing china. The kiln being brought to its full heat, the vessel is placed first at its mouth to heat it gradually, and then put into the interior of the fusion of the glaze. In practice it has been found advantageous also to dust the glaze powder over the fused glaze, and apply a second fluxing heat in the oven. The enamel, by this double application, becomes much smoother and sounder.

Messrs. Kenrick of West Bromwich having produced in their factory and sent into the market some excellent specimens of enamelled saucepans of cast iron, were sued by Messrs. Clarke for an invasion of their patent rights; but after a long litigation in chancery, the patentees were nonsuited in the court of exchequer. The previous process of cleansing with dilute sulphuric acid appeared by the evidence on the trial to have been given up by the patentees, and it was also shown by their own principal scientific witness that a good enamelled iron saucepan could be made by Hickling's specification. In fact, the formulæ by which a good enamel may be compounded are almost innumerable; so that a patent for such a purpose seems to be untenable, or at least most easily evaded. I have exposed the finely-enamelled saucepans of Messrs. Kenrick to very severe trials, having fused even chloride of calcium in them, and have found them to stand the fire very perfectly without chipping or cracking. I consider such a manufacture to be one of the greatest improvements recently introduced into domestic economy; such vessels being remarkably clean, salubrious, and adapted to the most delicate culinary operations of boiling, stewing, making of jellies, preserves, &c. They are also admirably fitted for preparing pharmaceutical decoctions, and ordinary extracts.

The enamel of the said saucepans is quite free from lead, in consequence of the glass which enters into its composition being quite free from that metal. In several of the saucepans which were at first sent into the market by Messrs. Clarke, their enamel was found on analysis by several chemists to contain a notable proportion of oxide of lead. In consequence of the quantity of borax and soda in the glaze, this oxide was so readily acted upon by acids, that sugar of lead was formed by digesting vinegar in them with a gentle heat. The presence of this noxious metal formed, in my opinion, a legitimate ground for contesting the patent, being in direct violation of the terms of the specification. Messrs. Kenwick's wares have been always free from this deleterious metal. Messrs. Clarke, I understand, have for some time been careful to reject from

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their enamel-composition all glass which contains lead; and they now manufacture also wholesome enamelled ware. Thus the public have profited in a most important point by the aforesaid litigation.

Enamelled iron saucepans had been many years ago imported from Germany, and sold in London. I had occasion to analyze their enamel, and found to my surprise that it contains abundance of litharge or oxide of lead. The Prussian government has issued an edict prohibiting the use of lead in the enamelling of saucepans, which are so extensively manufactured in Peiz, Gleiwitz, &c. Probably the German ware sent to England was fabricated for exportation, with an enamel made to flux easily by a dose of litharge. The composition of the said enamel is nearly the same with that which I found upon some of the earlier saucepans of Messrs. Clarke. Had their patent been sustained, the important legal question would have arisen, whether it gave the patentees the power of preventing dealers from continuing to sell what they had been habitually doing for a great many years.

A suitable oven or muffle for lining or coating metals with enamel may have the following dimensions:—

The outside, 8 feet square, with 14-inch walls; the interior muffle, 4 feet square at bottom, rising 6 inches at the sides, and then arched over; the crown may be 18 inches high from the floor: the muffle should be built of fire-brick, 2½ inches thick. Another arch is turned over the first one, which second arch is 7 inches wider at the bottom, and 4 inches higher at the top. A 9-inch wall under the bottom of the muffle at its centre divides the fireplaces into two, of 16 inches width each, and 3 feet 3 inches long. The flame of the fire plays between the two arches and up through a 3-inch flue in front, and issues from the top of the arch through three holes, about 4 inches square; these open into a flue, 10+9 inches, which runs into the chimney.

The materials for the enamel body (ground flint, potter's clay, and borax) are first mixed together and then put into a reverberatory furnace, 6 feet 6 inches long, by 3 feet 4 wide, and 12 inches high. The flame from an 18-inch fireplace passes over the hearth. The materials are spread over the floor of the oven, about 6 inches thick, and ignited or fritted for four or five hours, until they begin to heave and work like yeast, when another coating is put on the top, also 6 inches thick, and fired again, and so on the whole day. If it be fired too much, it becomes hard and too refractory to work in the muffles. The glaze is worked in an oven similar to the above. It may be composed of about one half borax and one half of Cornish stone in a yellowish powder procured from the potteries. This is fritted for 10 hours, and then fused into a glass which is

Enamelled Cast-Iron. Cast-iron vessels have been exceedingly well enamelled under two different patents within these few years; at first, by Mr. Clark, of Wolverhampton, and in November, 1846, by Messrs. Kenrick, of West Bromwich. Before the enamel is applied, the surface of the iron should be made quite clean and bright. The enamel consists of two coats; the one forming the body, and the other the glaze. The body is made by fusing 100 lbs. of ground flints, and 75 of borax, and grinding 40 lbs. of this frit with 5 lbs. of potter's clay in water till it is brought to the consistence of a pap. A coating of this pap being applied and dried, but not hard, the glaze powder is sifted over it. This consists of 100 parts of Cornish stone, in fine powder, 117 of borax, 35 of soda-ash, 35 of nitre, 35 of sifted slaked lime, 13 of white sand, and 50 of pounded white glass. These are all fused together; the frit obtained is pulverized. Of this powder 45 pounds are mixed with 1 pound of soda-ash, in hot water; and the mixture being dried in a stove is the glaze powder. When this powder has been very finely sifted over the body coat, the cast iron article is put into a stove, kept at a temperature of about 212°, to dry it hard; after which it is set in a muffle kiln to be fused into a glaze.

The inside of pipes is enamelled (after being cleaned) by pouring the above body composition through them while the pipe is being turned about, to insure its being uniformly coated. After the body has become set, the glaze pap is poured in in a like manner. The pipe is finally fired in the kiln.

Enamelled Leather. Instead of enamelling the grain surface as heretofore, Mr. Nossiter removes that surface by splitting or puffing, and then produces what is called "a finish" upon the surface thus formed, by means of a roller, or glass instrument. Or the flesh side may be thus prepared for enamelling; and it is less liable to crack, and the enamel to become cloudy, than the grain side. He also shaves hides and skins by knives set tangentially upon a rotary axis, with a certain degree of obliquity. He squeezes the grease out of the skins by hard pressure between rollers; and he uses a rotary brush to clear away all filth.

Enamelling Metals. In February, 1847, Mr. Walton patented a method of

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enamelling copper and other vessels, by coating them (after their surfaces are scaled by heat and cleaned) with powders of a vitrifiable kind applied in a thin pasty state with a brush, then drying and firing them. His formula for the composition is as follows: 6 parts of flint glass, 3 of borax, 1 of red lead, and 1 of oxide of tin; mixed, fritted, ground into powder, made into a thin paste with water, applied, dried, and fused on by the heat of an enamel kiln (see POTTERY). A second and even a third coat is prescribed. Into the second he puts calcined bone in powder, with china clay and carbonate of potash. These materials are fritted, ground, and mixed with certain of the former vitrifiable materials. Being reduced to a creamy consistence with water in a porcelain mill, the mixture is painted on with a brush, or applied by dipping, dried, and fired. One of his formulæ consists of 4 parts of ground felspar, 4 of white sand, 4 of carbonate of potash, 1 of arsenic, 6 of borax, 1 of oxide of tin, 1 of nitre, 1 of whiting—being in my opinion a most injudicious farrago, for which a much better and simpler combination of vitrifiable china-like materials might be substituted.—*Newton's Journal*, XXXI. p. 183.

EPSOM SALTS. Sulphate of Magnesia.

EQUIVALENTS, CHEMICAL. (*Stöchiometrie*, Germ.) This expression was first employed by Dr. Wollaston, to denote the primary proportions in which the various chemical bodies reciprocally combine; the numbers representing these proportions being referred to one standard substance of general interest, such as oxygen or hydrogen reckoned unity, or 1,000. Dr. Dalton, who is the true author of the grand discovery of definite and multiple chemical ratios, calls these equivalent numbers *atomic weights*, when reduced to their lowest terms, either hydrogen or oxygen being the radix of the scale. Though it belongs to a chemical work to discuss the principles and develop the applications of the Atomic Theory, I shall be careful, upon all proper occasions, to point out the vast advantages which the chemical manufacturer may derive from it, and to show how much he may economize and improve his actual processes by its means. See ELEMENT.

ESSENCES are either ethereous oils, in which all the fragrance of vegetable products reside; or the same combined and diluted with alcohol. See OILS, ETHEREOUS.

ESSENCE D'ORIENT, the name of a pearly looking matter procured from the blay or bleak, a fish of the genus *cyprinus*. This substance, which is found principally at the base of the scales, is used in the manufacture of artificial pearls. A large quantity of the scales being scraped into water in a tub, are there rubbed between the hands to separate the shining stuff, which subsides on repose. The first water being decanted, more is added with agitation till the essence is thoroughly washed from all impurities; when the whole is thrown upon a sieve; the substance passes through, but the scales are retained. The water being decanted off, the essence is procured in a viscid state, of a bluish white color, and a pearly aspect. The intestines of the same fish are also covered with this beautiful glistening matter. Several other fish yield it, but in smaller proportion. When well prepared, it presents exactly the appearance and reflections of the real pearls, or the finest mother of pearl; properties which are probably owing to the interposition of some portions of this same substance, between the laminæ of these shelly concretions. Its chemical nature has not been investigated; it putrefies readily when kept moist, an accident which may, however, be counteracted by water of ammonia. See PEARLS.

ETCHING *Varnish*. (*Aetzgrund-Deckfirniss*, Germ.) Though the practice of this elegant art does not come within the scope of our Dictionary, the preparation of the varnishes, and of the biting menstrua which it employs, legitimately does.

The varnish of Mr. Lawrence, an English artist resident in Paris, is made as follows: Take of virgin wax and asphaltum, each two ounces, of black pitch and burgundy-pitch each half an ounce. Melt the wax and pitch in a new earthenware glazed pot, and add to them, by degrees, the asphaltum, finely powdered. Let the whole boil till such time as that, taking a drop upon a plate, it will break when it is cold, on bending it double two or three times betwixt the fingers. The varnish, being then enough boiled, must be taken off the fire, and after it cools a little, must be poured into warm water that it may work the more easily with the hands, so as to be formed into balls, which must be kneaded, and put into a piece of taffety for use.

Care must be taken, first, that the fire be not too violent, for fear of burning the ingredients, a slight simmering being sufficient; secondly, that whilst the asphaltum is putting in, and even after it is mixed with the ingredients, they should be stirred continually with the spatula; and thirdly, that the water into which this composition is thrown should be nearly of the same degree of warmth with it, in order to prevent a kind of cracking that happens when the water is too cold.

The varnish ought always to be made harder in summer than in winter, and it will become so if it be suffered to boil longer, or if a greater proportion of the asphaltum or brown rosin be used. The experiment above mentioned, of the drop suffered to cool, will determine the degree of hardness or softness that may be suitable to the season when it is used.

Preparation of the hard varnish used by Callot, commonly called the Florence Varnish:—Take four ounces of fat oil very clear, and made of good linseed oil, like that used by painters; heat it in a clean pot of glazed earthenware, and afterwards put to it four ounces of mastick well powdered, and stir the mixture briskly till the whole be well melted, then pass the mass through a piece of fine linen into a glass bottle with a long neck, that can be stopped very securely; and keep it for the use that will be explained below.

Method of applying the soft varnish to the plate, and of blackening it:—The plate being well polished and burnished, as also cleansed from all greasiness by chalk or Spanish white, fix a hand-vice on the edge of the plate where no work is intended to be, to serve as a handle for managing it when warm; then put it upon a chafing dish, in which there is a moderate fire, and cover the whole plate equally with a thin coat of the varnish; and whilst the plate is warm, and the varnish upon it in a fluid state, beat every part of the varnish gently with a small ball or dauber made of cotton tied up in taffety, which operation smooths and distributes the varnish equally over the plate.

When the plate is thus uniformly and thinly covered with the varnish, it must be blackened by a piece of flambeau, or of a large candle which affords a copious smoke; sometimes two or even four such candles are used together for the sake of despatch, that the varnish may not grow cold, which if it does during the operation, the plate must be heated again, that it may be in a melted state when that operation is performed; but great care must be taken not to burn it, which, when it happens, may be easily perceived by the varnish appearing burnt, and losing its gloss.

The menstruum used and recommended by Turrell, an eminent London artist, for etching upon steel, was prepared as follows:—

Take	Pyroligneous acid	4 parts by measure,
	Alcohol	1 part, mix, and add
	Nitric acid	1 part.

This mixed liquor is to be applied from 1½ to 15 minutes, according to the depth desired. The nitric acid was employed of the strength of 1·28—the double aquafortis of the shops.

The *eau forte* or menstruum for copper, used by Callot, as also by Piranesi, with a slight modification, is prepared with 8 parts of strong French vinegar,

4 parts of verdigris,
4 ditto sea salt,
4 ditto sal ammoniac,
1 ditto alum,
16 ditto water.

The solid substances are to be well ground, dissolved in the vinegar, and diluted with the water; the mixture is now to be boiled for a moment, and then set aside to cool. This menstruum is applied to the washed, dried, and varnished plate, after it has suffered the ordinary action of aquafortis, in order to deepen and finish the delicate touches. It is at present called the *eau forte à passer.*

ETHER is the name of a class of very light, volatile, inflammable, and fragrant spirituous liquids, obtained by distilling, in a glass retort, a mixture of alcohol with almost any strong acid. Every acid modifies the result, in a certain degree, whence several varieties of ether are produced. The only one of commercial importance is sulphuric ether, which was first made known under the name of *sweet oil of vitriol,* in 1540, by the receipt of Walterus Cordus. Froberus, 190 years after that date, directed the attention of chemists afresh to this substance, under the new denomination of *ether.*

There are two methods of preparing it; by the first, the whole quantity of acid and alcohol are mixed at once, and directly subjected to distillation; by the second, the alcohol is admitted, in a slender streamlet, into a body of acid previously mixed with a little alcohol, and heated to 220° Fahr.

1. Mix equal weights of alcohol at spec. grav. 0·830, and sulphuric acid at 1·842, by introducing the former into a large tubulated retort, giving it a whirling motion, so that the alcohol may revolve round a central conical cavity. Into this species of whirlpool the acid is to be slowly poured. The mixture, which becomes warm, is to be forthwith distilled by attaching a spacious receiver to the retort, and applying the heat of a sand-bath. The formation of ether takes place only at a certain temperature. If the contents of the retort be allowed to cool, and be then slowly heated in a water-bath, alcohol alone will come over for some time without ether, till the mixture acquires the

proper degree of heat. The first receiver should be a globe, with a tube proceeding from its bottom, into a second receiver, of a cylindric shape, surrounded with ice-cold water. The joints must be well secured by lutes, after the expanded air has been allowed to escape. The liquid in the retort should be kept in a steady state of ebullition. The ether, as long as it is produced, condenses in the balloon and neck of the receiver in striæ; when these disappear the process is completed. The retort must now be removed from the sand; otherwise it would become filled with white fumes containing sulphurous acid, and denser striæ would flow over, which would contaminate the light product with a liquid called sweet oil of wine.

The theory of etherification demonstrates that when strong sulphuric acid is mixed with alcohol, there is formed, on the one hand, a more aqueous sulphuric acid, and, on the other, sulphovinic acid. When this mixture is made to boil, the sulphovinic acid is decomposed, its dihydrate of carbon combines with the alcohol, and constitutes ether; while the proportion of sulphovinic acid progressively diminishes. Mr. Hennell, of the Apothecaries' Hall, first explained these phenomena, and he was confirmed in his views by the interesting researches of Serullas. The acid left in the retort is usually of a black color, and may be employed to convert into ether half as much alcohol again; an experiment which may be repeated several times in succession.

The most profitable way of manufacturing ether has been pointed out by Boullay. It consists in letting the alcohol drop in a slender stream into the acid, previously heated to the etherifying temperature. If the acid in this case were concentrated to 1·846, the reaction would be too violent, and the ether would be transformed into bicarbureted hydrogen (dihydrate of carbon). It is therefore necessary to dilute the acid down to the density of 1·780; but this dilution may be preferably effected with alcohol, instead of water, by mixing three parts of the strongest acid with 2 of alcohol, specific gravity 0·830, and distilling off a portion of the ether thereby generated; after which the stream of alcohol is to be introduced into the tubulure of the retort through a small glass tube plunged into the mixture; this tube being the prolongation of a metallic syphon, whose shorter leg dips into a bottle filled with the alcohol. The longer leg is furnished with a stop-cock, for regulating at pleasure the alcoholic streamlet. The distilled vapors should be transmitted through a worm of pure tin, surrounded by cold water, and the condensed fluid received in a glass bottle. The quantity of alcohol which can be thus converted into ether by a given weight of sulphuric acid, has not hitherto been accurately determined; but it is at least double. In operating in this way, neither sulphurous acid nor sweet oil of wine is generated, while the residuary liquid in the retort continues limpid and of a merely brownish yellow color. No sulphovinic acid is formed, and according to the experiments of Geiger, the proportion of ether approaches to what theory shows to be the maximum amount. In fact, 57 parts of alcohol of 0·83 sp. grav. being equivalent to 46·8 parts of anhydrous alcohol, yield, according to Geiger, 33½ parts of ether; and by calculation they should yield 37¼.

The ether of the first distillation is never pure, but always contains a certain quantity of alcohol. The density of that product is usually 0·78, and if prepared by the first of the above methods, contains, besides alcohol, pretty frequently sulphurous acid, and sweet oil of wine; impurities from which it must be freed. Being agitated with its bulk of milk of lime, both the acid and the alcohol are removed at the same time; and if it be then decanted and agitated, first with its bulk of water, next decanted into a retort containing chloride of calcium in coarse powder, and distilled, one third of perfectly pure ether may be drawn over. Gay Lussac recommends to agitate the ether, first with twice its volume of water, to mix it, and leave it in contact with powdered unslaked lime for 12 or 14 hours, and then to distil off one third of pure ether. The remaining two thirds consist of ether containing a little alcohol. If in preparing ether by Boullay's method, the alcohol be too rapidly introduced, much of this liquid will come over unchanged. If in this state the ether be shaken with water, a notable quantity of it will be absorbed, because weak alcohol dissolves it very copiously. The above product should therefore be re-distilled, and the first half that comes over may be considered as ether, and treated with water and lime. The other half must be exposed afresh to the action of sulphuric acid.

Pure ether possesses the following properties. It is limpid, of spec. grav. 0·713, or 0·715 at 60°; has a peculiar penetrating strong smell; a taste at first acrid, burning, sweetish, and finally cooling. It has neither an acid nor alkaline reaction; is a non-conductor of electricity, and refracts light strongly. It is very volatile, boiling at 96° or 97° F., and produces by its evaporation a great degree of cold. At the temperature of 62·4, the vapor of ether balances a column of mercury 15 inches high, or half the weight of the atmosphere. When ether is cooled to —24° F. it begins to crystallize in brilliant white plates, and at —47° it becomes a white crystalline solid. When vapor of ether is made to traverse a red hot porcelain tube, it deposites within it one half per cent. of charcoal, and there are condensed in the receiver one and two thirds per cent. of a brown oil, partly in crystalline scales, and partly viscid. The crystalline portion is soluble in alcohol, but the viscid only in ether. The remainder of the decomposed ether consists of bi-carbureted hydrogen gas, tetrahydric carburet, carbonic oxyde gas, and one per cent. at most of gaseous carbonic acid.

Ether takes fire readily, even at some distance from a flame, and it should not therefore be poured from one vessel to another in the neighborhood of a lighted candle. It may be likewise set on fire by the electric spark. It burns all away with a bright fuliginous flame. When the vapor of ether is mixed with 10 times its volume of oxygen, it burns with a violent explosion, absorbs 6 times its bulk of oxygen, and produces 4 times its volume of carbonic acid gas.

Ether alters gradually with contact of air; absorbing oxygen, and progressively changing into acetic acid and water. This conversion takes place very rapidly when the ether is boiled in an open vessel, while the acid enters into a new combination forming acetic ether. Ether should be preserved in bottles perfectly full and well corked, and kept in a cool place, otherwise it becomes sour, and is destroyed. In contains in this state 15 per cent. of its bulk of azote, but no oxygen gas, as this has combined with its elements. Ether is composed of oxygen 21·24; hydrogen 13·85; carbon 65·05. This composition may be represented by 1 prime equivalent of water, and 4 primes of bi-carburetted hydrogen gas; in other words, ether contains for 1 prime of water, once as much olefiant gas as alcohol, and its prime equivalent is therefore 468·15 to oxygen 100. By my analysis, as published in the Phil. Trans. for 1822, ether is composed of oxygen 27·10; hydrogen 13·3; and carbon 59·6 in 100 parts. The density of my ether was 0·700. One volume of vapor of ether consists of one volume of aqueous vapor and two volumes of olefiant gas (bi-carbureted hydrogen), while alcohol consists of two volumes of each.

ETHER, ACETIC, is used to flavor silent corn spirits in making imitation brandy. It may be prepared by mixing 20 parts of acetate of lead, 10 parts of alcohol, and 11½ of concentrated sulphuric acid; or 16 of the anhydrous acetate, 5 of the acid, and 4½ of absolute alcohol; distilling the mixture in a glass retort into a very cold receiver, agitating along with weak potash ley the liquor which comes over, decanting the supernatant ether, and rectifying it by re-distillation over magnesia and ground charcoal.

Acetic ether is a colorless liquid of a fragrant smell and pungent taste, of spec. grav. 0·866 at 45° F., boiling at 166° F., burning with a yellowish flame, and disengaging fumes of acetic acid. It is soluble in 8 parts of water.

Acetic ether may be economically made with 3 parts of acetate of potash, 3 of very strong alcohol, and 2 of the strongest sulphuric acid, distilled together. The first product must be re-distilled along with one fifth of its weight of sulphuric acid; as much ether will be obtained as there was alcohol employed.

ETHIOPS is the absurd name given by the alchemists to certain black metallic preparations. Martial ethiops was the black oxyde of iron; mineral ethiops, the black sulphuret of mercury; and ethiops *per se*, the black oxyde of mercury.

EVAPORATION (Eng. and Fr.; *Abdampfen; Abdunsten*, Germ.) is the process by which any substance is converted into, and carried off in, vapor. Though ice, camphor, and many other solids evaporate readily in dry air, I shall consider, at present, merely the vaporization of water by heat artificially applied.

The vapor of water is an elastic fluid, whose tension and density depend upon the temperature of the water with which it is in contact. Thus the vapor rising from water heated to 165° F. possesses an elastic force capable of supporting a column of mercury 10·8 high; and its density is such that 80 cubic feet of such vapor contain one pound weight of water; whereas 32½ cubic feet of steam of the density corresponding to a temperature of 212° and a pressure of 30 inches of mercury, weigh one pound. When the temperature of the water is given, the elasticity and specific gravity of the vapor emitted by it may be found.

Since the vapor rises from the water only in virtue of the elasticity due to its gaseous nature, it is obvious that no more can be produced, unless what is already incumbent upon the liquid have its tension abated, or be withdrawn by some means. Suppose the temperature of the water to be midway between freezing and boiling, viz., 122° Fahr., as also that of the air in contact with it, to be the same but replete with moisture, so that its interstitial spaces are filled with vapor of corresponding elasticity and specific gravity with that given off by the water, it is certain that no fresh formation of vapor can ake place in these circumstances. But the moment a portion of vapor is allowed to es cape, or is drawn off by condensation to another vessel, an equivalent portion of vapor will be immediately exhaled from the water.

The pressure of the air and of other vapors upon the surface of water in an open vessel, does not prevent evaporation of the liquid; it merely retards its progress. Experience shows that the space filled with an elastic fluid, as air or other gaseous body, is capable of receiving as much aqueous vapor as if it were vacuous, only the repletion of that space with the vapor proceeds more slowly in the former predicament than in the latter, but in both cases it arrives eventually at the same pitch. Dr. Dalton has very ingeniously proved, that the particles of aeriform bodies present no permanent obstacle to the introduction of a gaseous atmosphere of another kind among them, but merely obstruct its diffusion momentarily, as if by a species of friction. Hence, exhalation at atmospheric temperatures is promoted by the mechanical diffusion of the vapors through the air with ventilating fans or chimney draughts; though under brisk ebullition, the force of the steam readily overcomes that mechanical obstruction.

The quantities of water evaporated under different temperatures in like times, are proportional to the elasticities of the steam corresponding to these temperatures. A vessel of boiling water exposing a square foot of surface to the fire, evaporates 725 grains in the minute; the elasticity of the vapor is equivalent to 30 inches of mercury. To find the quantity that would be evaporated from the same surface per minute at a heat of 88° F. At this temperature the steam incumbent upon water is capable of supporting 1·28 inch of mercury; whence the rule of proportion is 30 : 1·28 : : 725 : 30·93; showing that about 31 grains of water would be evaporated in the minute. If the air contains already some aqueous vapor, as it commonly does, then the quantity of evaporation will be proportional to the difference between the elastic force of that vapor, and what rises from the water.

Suppose the air to be in the hygrometric state denoted by 0·38 of an inch of mercury, then the above formula will become: 30 : 1·28 — 0·38 : : 725 : 21·41; showing that not more than 21½ grains would be evaporated per minute under these circumstances.

The elastic tension of the atmospheric vapor is readily ascertained by the old experiment of Le Roi, which consists in filling a glass cylinder (a narrow tumbler for example) with cool spring water, and noting its temperature at the instant it becomes so warm that dew ceases to be deposited upon it. This temperature is that which corresponds to the elastic tension of the atmospheric vapor. See Vapor, Table of.

Whenever the elasticity of the vapor, corresponding to the temperature of the water, is greater than the atmospheric pressure, the evaporation will take place not only from its surface, but from every point in its interior; the liquid particles throughout the mass assuming the gaseous form, as rapidly as they are actuated by the caloric, which subverts the hydrostatic equilibrium among them, to constitute the phenomena of ebullition. This turbulent vaporization takes place at any temperature, even down to the freezing point, provided the pneumatic pressure be removed from the liquid by the air pump, or any other means. Ebullition always accelerates evaporation, as it serves to carry off the aqueous particles not simply from the surface, but from the whole body of the water.

The vapors exhaled from a liquid at any temperature, contain more heat than the fluid from which they spring; and they cease to form whenever the supply of heat into the liquid is stopped. Any volume of water requires for its conversion into vapor *five and a half times* as much heat as is sufficient to heat it from the freezing to the boiling temperature. The heat, in the former case, seems to be absorbed, being inappreciable by the thermometer; for steam is no hotter than the boiling water from which it rises. It has been therefore called *latent heat;* in contradistinction to that perceived by the touch and measured by the thermometer, which is called *sensible heat.* The quantity of heat absorbed by one volume of water in its conversion into steam, is about 1000° Fahr.; it would be adequate to heat 1000 volumes of water, one degree of the same scale; or to raise one volume of boiling water, confined in a non-conducting vessel, to 1180°. Were the vessel charged with water so heated, opened, it would be instantaneously emptied by vaporization, since the whole caloric equivalent to its constitution as steam, is present. When, upon he other hand, steam is condensed by contact with cold substances, so much heat is set free as is capable of heating five and a half times its weight of water, from 32° to 212° F. If the supply of heat to a copper be uniform, five hours and a half will be required to drive off its water in steam, provided one hour was taken in heating the water, from the freezing to the boiling pitch, under the atmospherical pressure.

Equal weights of vapor of any temperature contain equal quantities of heat; for example, the vapor exhaled from one pound of water, at 77° F., absorbs during its formation, and will give out in its condensation, as much heat as the steam produced by one pound of water, at 212° F. The first portion of vapor with a tension=30 inches, occupies a space of 27·31 cubic feet; the second, with a tension of 0·92 inch, occupies a space of 890 cubic feet.* Suppose that these 890 volumes were to be compressed into 27·31 in a cylinder capable of confining the heat, the temperature of the vapor would rise from 77° to 212°, in virtue of the condensation, as air becomes so hot by com-

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* One pound avoirdupois of water contains 27·72 cubic inches; one cubic inch of water forms 1696 cubic inches of steam at 212° F.: therefore one pound of water will form 27·31 cubic feet of such steam: and 0·92 30 : : 27·31 : 890 cubic feet.

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pression in a syringe, as to ignite *amadou*. The latent heat of steam at 212° F. is $1180°-180=1000$; that of vapor, at 77°, is $1180-45=1135°$; so that, in fact, the lower the temperature at which the vapor is exhaled, the greater is its latent heat, as Joseph Black and James Watt long ago proved by experiments upon distillation and the steam engine.

From the preceding researches it follows, that evaporation may be effected upon two different plans:—

1. Under the ordinary pressure of the atmosphere; and that either,

A, by external application of heat to boilers with *a*, an open fire; *b*, steam; *c*, hot liquid *media*.

B, by evaporation with air; *a*, at the ordinary temperature of the atmosphere; *b*, by currents of warm air.

2. Under progressively lower degrees of pressure than the atmospheric, down to evaporation in as perfect a vacuum as can be made.

It is generally affirmed, that a thick metallic boiler obstructs the passage of the heat through it so much more than a thin one, as to make a considerable difference in their relative powers of evaporating liquids. Many years ago, I made a series of experiments upon this subject. Two cylindrical copper pans, of equal dimensions, were provided; but the metal of the one was twelve times thicker than that of the other. Each being charged with an equal volume of water, and placed either upon the same hot plate of iron, or immersed, to a certain depth, in a hot solution of muriate of lime, I found that the ebullition was greatly more vigorous in the thick than in the thin vessel, which I ascribed to the conducting substance up the sides, above the contact of the source of heat, being 12 times greater in the former case than in the latter.

If the bottom of a pan, and the portions of the sides, immersed in a hot fluid medium, solution of caustic potash or muriate of lime, for example, be corrugated, so as to contain a double expanse of metallic surface, that pan will evaporate exactly double the quantity of water, in a given time, which a like pan, with smooth bottom and sides, will do immersed equally deep in the same bath. If the corrugations contain three times the quantity of metallic surface, the evaporation will be threefold in the above circumstances. But if the pan, with the same corrugated bottom and sides, be set over a fire, or in an oblong flue, so that the current of flame may sweep along the corrugations, it will evaporate no more water from its interior than a smooth pan of like shape and dimensions placed alongside in the same flue, or over the same fire. This curious fact I have verified upon models constructed with many modifications. Among others, I caused a cylindrical pan, 10 inches diameter, and 6 inches deep, to be made of tin-plate, with a vertical plate soldered across its diameter; dividing it into two equal semi-cylindrical compartments. One of these was smooth at the bottom, the other corrugated; the former afforded as rapid an evaporation over the naked fire as the latter, but it was far outstripped by its neighbor when plunged into the heated liquid medium.

If a shallow pan of extensive surface be heated by a subjacent fire, by a liquid medium or a series of steam pipes upon its bottom; it will give off less vapor in the same time when it is left open, than when partially covered. In the former case, the cool incumbent air precipitates by condensation a portion of the steam, and also opposes considerable mechanical resistance to the diffusion of the vaporous particles. In the latter case, as the steam issues with concentrated force and velocity from the contracted orifice, the air must offer less proportional resistance, upon the known hydrostatic principle of the pressure being as the areas of the respective bases, in communicating vessels.

In evaporating by surfaces heated with ordinary steam, it must be borne in mind that a surface of 10 square feet will evaporate fully one pound of water per minute, or $725 \times 10 = 7250$ gr., the same as over a naked fire; consequently the condensing surface must be equally extensive. Suppose that the vessel is to receive of water 2500 lbs., which corresponds to a boiler 5 feet long, 4 broad, and 2 deep, being 40 cubic feet by measure, and let there be laid over the bottom of this vessel 8 connected tubes each 5 inches in diameter and 5 feet long, possessing therefore a surface of 5 feet square. If charged with steam, they will cause the evaporation of half a pound of water per minute. The boiler to supply the steam for this purpose must expose a surface of 5 square feet to the fire. It has been proved experimentally that 10 square feet surface of thin copper can condense 3 lbs. of steam per minute, with a difference of temperature of 90 degrees Fahr. In the above example, 10 square feet evaporate 1 lb. of water per minute; the temperature of the evaporating fluid being 212° F., consequently $3 : 1 : 90 : \frac{90}{3}$. During this evaporation the difference of the temperature is therefore $= 30°$. Consequently the heat of the steam placed in connexion with the interior of the boiler, to produce the calculated evaporation, should be, $212 + 30 = 242°$, corresponding to an elastic force of 53·6 inches of mercury. Were the temperature of

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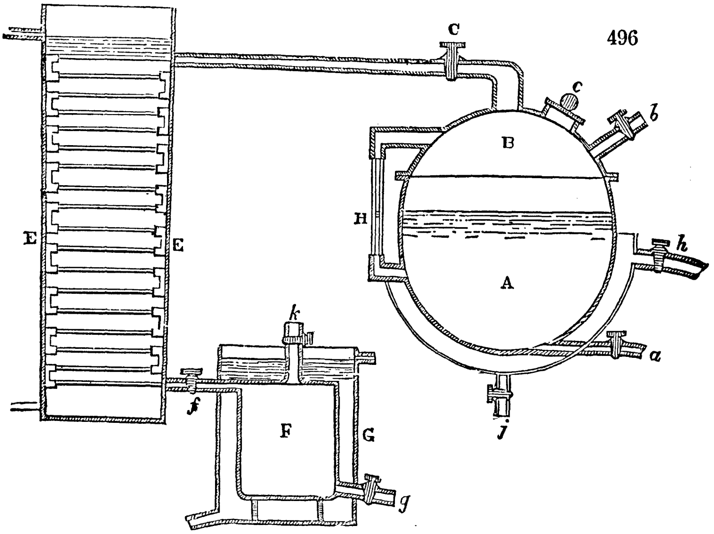
the steam only 224, the same boiler in the same time would produce a diminished quantity of steam, in the proportion of 12 to 30; or to produce the same quantity the boiler or tubular surface should be enlarged in the proportion of 30 to 12. In general, however, steam boilers employed for this mode of evaporation are of such capacity as to give an unfailing supply of steam.

I shall now illustrate by some peculiar forms of apparatus, different systems of evaporation. *Fig.* 496 explains the principles of evaporating in vacuo. A B represents a pan or kettle charged with the liquor to be evaporated. The somewhat wide orifice *c*, secured with a screw-plug, serves to admit the hand for the purpose of cleaning it thoroughly out when the operation is finished; *h* is the pipe of communication with the steam boiler; *b* is a tube prolonged and then bent down with its end plunged into the liquor to be evaporated, contained in the charging back, (not shown in the figure). H is a glass tube communicating with the vacuum pan at the top and bottom, to show by the height of the column the quantity of liquid within. The eduction evaporating pipe C is provided with a stop-cock to cut off the communication when required. *i* is a tube for the discharge of the air and the water from the steam-case or jacket; the refrigerator E is best formed of thin copper tubes about 1 inch in diameter, arranged zig-zag or spirally like the worm of a still in a cylinder. The small air-tight condenser F, connected with the efflux pipe *f* of the refrigerator, is furnished below with a discharge cock *g*, and surrounded by a cooling case, for the collection of the water condensed by the refrigerator. In its upper part there is a tube *k*, also furnished with a cock, which communicates with the steam boiler, and through which the pan A B is heated.



The operation of this apparatus is as follows: after opening the cocks C, *f*, *g*, and before admitting the cold water into the condenser E, the cock of the pipe *k* is opened, in order that by injecting steam it may expel the included air; after which the cocks *k* and *g* are to be shut. The water must now be introduced into the condenser, and the cock *b* opened, whereon the liquid to be evaporated rises from the charging back, through the tube *b*, and replenishes the vacuum pan to the proper height, as shown by the register glass tube H. Whenever the desired evaporation or concentration is effected, the cock C must be closed, the pipe *k* opened, so as to fill the pan with steam, and then the efflux cock *a* is opened to discharge the residuary liquor. By shutting the cocks *a* and *k*, and opening the cock *b*, the pan will charge itself afresh with liquor, and the operation will be begun anew, after *b* has been shut and C opened.

The contents of the close water cistern F, may be drawn off during each operation. For this purpose, the cock *f* must first be shut, the cold water is to be then run out of the condenser G, and *k* and *g* are to be opened. The steam entering by *k* makes the water flow, but whenever the steam itself issues from the cock *g*, this orifice must be immediately shut, the cock *f* opened, and the cold water again introduced, whereupon the condensed water that had meanwhile collected in the under part of the refrigerator, flows off into the condenser vessel F. Since some air always enters with the liquor sucked into the pan, it must be removed at the time of drawing off the water from the two condensers, by driving steam through the apparatus. This necessity will be less urgent if the liquor be made to boil before being introduced into the vacuum pan.

Such an apparatus may be modified in size and arrangement to suit the peculiar object in view, when it will be perfectly adapted for the concentration of extracts of every kind, as well as saline solutions containing vegetable acids or alkalis. The interior vessel of A B should be made of tinned or plated copper. For an account of Howard's vacuum pan, made upon the same principle, see SUGAR.

When a boiler is set over a fire, its bottom should not be placed too near the grate, lest it refrigerate the flame, and prevent that vivid combustion of the fuel essential to the maximum production of heat by its means. The evil influence of leaving too little room between the grate and the copper may be illustrated by a very simple experiment. If a small copper or porcelain capsule containing water be held over the flame of a candle a little way above its apex, the flame will suffer no abatement of brightness or size, but will continue to keep the water briskly boiling. If the capsule be now lowered into the middle of the flame, this will immediately lose its brightness, becoming dull and smoky, covering the bottom of the capsule with soot; and owing to the imperfect combustion, though the water is now surrounded by the flame, its ebullition will cease.

Fig. 497 is a section of two evaporating coppers *en suite*, so mounted as to favor the full combustion of the fuel. A is the hearth, in which wood or coal may be burned. For coal, the grate should be set higher and be somewhat smaller. *a* is the door for feeding the fire; *d*, an arch of fire-bricks over the hearth; *c*, a grate through which the ashes fall into the pit beneath, capable of being closed in front to any extent by a sliding door *b*. B and C are two coppers incased in brickwork; *f* the flue. At the end of the hearth near *m*, where the fire plays first upon the copper, the sole is made somewhat lower and wider, to promote the spreading of the flame under the vessel. The second copper, C, receives the benefit of the waste heat; it may be placed upon a higher level, so as to discharge its concentrated liquor by a stop-cock or syphon into the first. When coals are burned for heating such boilers, the grate should be constructed as shown in the figure of the brewing copper, page 151.

497

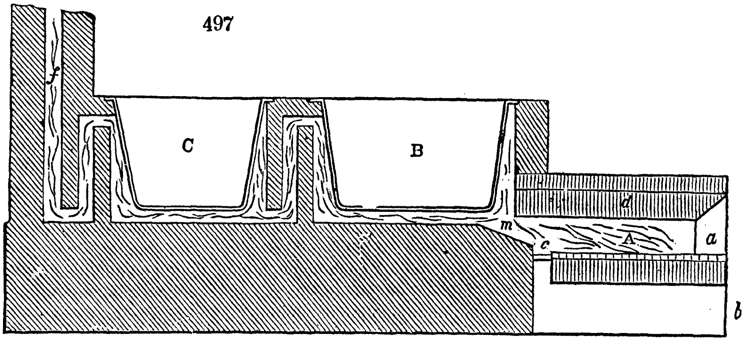
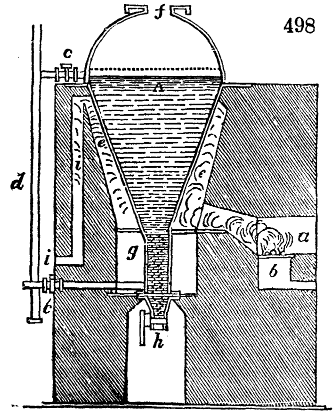


Fig. 498 represents a pan for evaporating liquids, which are apt, during concentration, to let fall crystals or other sediment. These would be injured either by the fire playing upon the bottom of the pan, or, by adhesion to it, they would allow the metal to get red hot, and in that state run every risk of being burnt or rent on the sudden intrusion of a little liquor through the incrustation. When large coppers have their bottoms planted in loam, so that the flame circulates in flues round their sides, they are said to be *cold-set*.

498



A is a pear-shaped pan, charged with the liquid to be evaporated; it is furnished with a dome cover, in which there is an opening with a flange *f*, for attaching a tube, to conduct the steam wherever it may be required. *a* is the fire-place; *b* the ash-pit. The conical part terminates below in the tube *g*, furnished with a stop-cock at its nozzle *h*. Through the tube *c d c′*, furnished above and below with the stop-cocks *c* and *c′*, the liquid is run from the charging back or reservoir. During the operation, the upper cock *c* is kept partially open, to replace the fluid as it evaporates; but the under cock *c'* is shut. The flame from the fire-place plays round the kettle in the space *e*, and the smoke escapes downwards through the flue *i* into the chimney. The lower cylindrical part *g* remains thus comparatively cool, and collects the crystalline or other solid matter. After some time, the under stop-cock *c'*, upon the supply-pipe, is to be opened to admit some of the cold liquor into the cylindrical neck. That cock being again shut, the sediment settled, and the large stop-cock (a horizontal slide-valve would be preferable) *h* opened, the crystals are suffered to descend into the subjacent receiver; after which the stop-cock *h* is shut, and the operation is continued. A construction upon this principle is well adapted for heating dyeing coppers, in which the sediment should not be disturbed, or exposed to the action of the fire. The fire-place should be built as for the brewing copper.

499

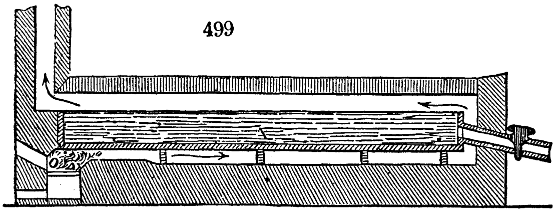
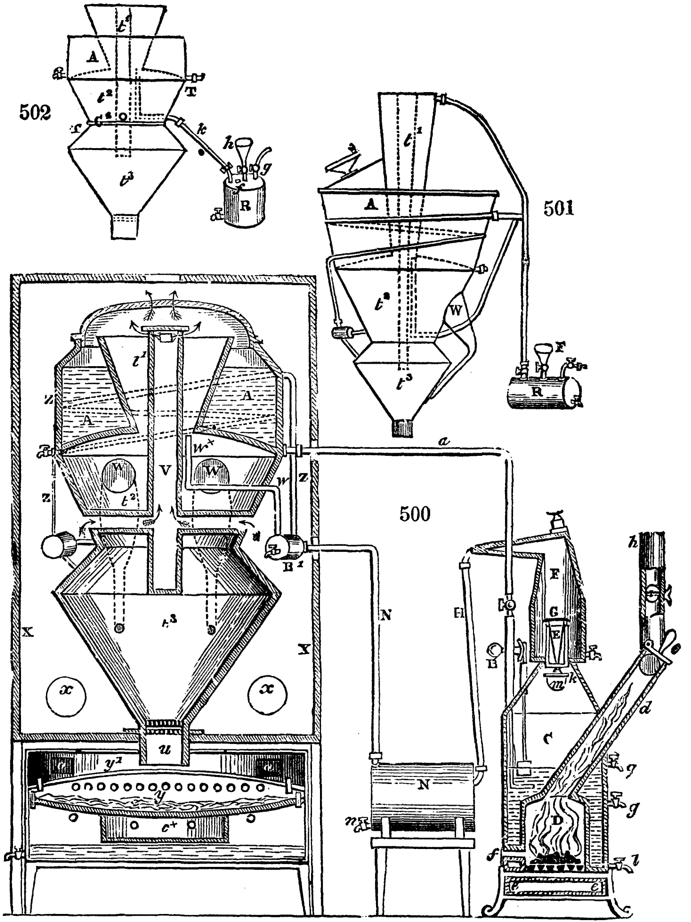


Fig. 499 represents an oblong evaporating pan, in which the flame, after beating along its bottom, turns up at its further end, plays back along its surface, and passes off into the chimney. A is a rectangular vessel, from 10 to 15 feet long, 4 to 6 feet broad, and 1 or 1½ feet deep. The fire-bricks, upon which the pan rests, are so arranged as to distribute the flame equably along its bottom.

For the following scheme of generating, purifying, and condensing steam, Mr. Charles Clarke, merchant, London, obtained a patent in January, 1843. His apparatus for converting sea-water, &c., economically into good fresh water, is represented in *figs.* 500, 501, 502. A is the supply cistern, which communicates with a pipe *a*, with a self-regulating eduction apparatus B. C is a strong wrought iron cylinder, fitted at bottom into a flanged ring-place *c*, and covered with a conical top; it is about two thirds filled with the water to be operated upon. D is a cylindrical furnace concentric with the water cylinder C; *d* is an upward air and water-tight tube, which serves both as a feed-pipe, through which the fuel is supplied to the furnace, and as a passage for the escape of the smoke and other gaseous products of combustion; *e* is a hinged trap-door through which the fuel is passed into the tube *d: h* is a chimney into which the pipe *d* terminates: and *i*, a damper, by which the degree of activity given to the furnace can be regulated at pleasure; *f* is an open air-pipe, which leads from the outside, through the boiler, into the furnace, a little way above the fire-bars, and assists in securing a good draught through the furnace into the chimney. To the water cylinder C there are attached gauge-cocks, *g g*, for ascertaining from time to time the height of the water; *l* is a cock or tap for drawing off the brine, and other residual matters which collect at the bottom of the boiler; *m* is a screw-cap and hole, through which access may be had to the interior of the water cylinder C, when it needs to be cleaned; E is a short pipe fitted into the conical top of the water cylinder C, which conveys the steam generated in it into the steam-head or receiver F: G is a concave plate, resting upon the top of the pipe E, a little larger than that pipe, and kept steady by a weight, *k*, of one or more pounds, suspended from it by wires. This plate prevents, in a great measure, the escape-water escaping into the steam-head (an accident commonly called *priming* in steam engines); because, till the steam has acquired a pressure exceeding that of the counterweight *k*, it cannot raise the weight G, so as to escape freely into the steam-head F, since any particle of water must, during the rising of the cap G, strike against it, and drop back, either into the water cylinder C, through the pipe E, or into the space round that pipe at the bottom of the steam-head H; whence it may be withdrawn by the cock shown in the drawing. H is a pipe which conveys the steam from the steam-head F to the rectifier R. This consists simply of a cylinder (about one third the size of the cylinder C) laid horizontally, in the lower part of which a body of water speedily collects, and serves to retain any particle of undecomposed matter, which may come over with the steam, as it continues to flow in from the boiler; whereby only its purer portions may pass off from the rectifier R, by the pipe N. *n* is a cock or tap, at the bottom of the cylinder R for drawing off its water occasionally; R^1 is a second steam-rectifier, like R, into which the steam passes from the pipe N, and is thereby still further purified; but when the proportion of saline matter is small, R^1 may be dispensed with, and for very foul water, two or three more such rectifiers may be added.

The condenser for liquefying the purified steam, and *aërating* the resulting water, is shown at t^1, t^2, t^3. It is composed of conical upright compartments communicating with each other; the chamber t^1 is surrounded by the water in the cistern A (slightly heated by the steam in that chamber), while the chambers t^2 and t^3 are exposed freely to the air. The lowest of these, t^3, terminates at bottom in a tube, u, containing at the mouth of the cone two or three plates of perforated zinc, for admission of the atmosphere. An upright steam-tight tube of zinc, at about the middle of the lowest chamber, t^3, and is continued to the top of the uppermost chamber, t^1, having two lateral branches. This tube is closed at its lower end, but open at top, and at the ends of the two branches, to give a draught of cool air into the tube, and a rapid flow of heated air from the top of the tube. W, W, are pipes which pass externally from about the middle of the chamber t^2, to near the bottom of the chamber t^3. At their tops they are of large dimensions, as represented, but diminish gradually to small pipes at bottom. Of these pipes, there should be as many as can be conveniently applied, in order that the process of condensation may be effectually promoted.



From the second rectifier, R^1, the steam is conveyed by a pipe, w, of gradually increasing dimensions, to near the top of the middle chamber, t, whence it diffuses itself through the three chambers, where it gets condensed. The hottest steam passes into t^1, and is there most powerfully condensed. The main body of the water produced therefrom, either drops directly into the bottom of the chamber t^3, or runs down the inclined sides of the chambers t^1, t^2, t^3, thence through the outer pipes W, W, and out at the bottom of the tube, getting partially aerated in its progress, by means of the air ascending constantly through the tube u.

Z, Z, is an auxiliar steam-pipe from the rectifier R^1, passing twice or thrice close round the water supplying the cistern, A, and terminating in a cylinder which communicates by pipes with the chambers, t^2 and t^3; whereby all the water thus condensed may fall through the perforated zinc plates, into the general discharge tube, *u*. x is an outer casing of wood or metal, leaving a small space round the condenser, with draught-holes, *x*, *x*, for the admission of air. The refrigerator is made of protected metal "(tinned copper?)," and divided into three compartments, y^1, y^2, y^3.

In the top of y^1, the end of the discharged tube *u* is inserted; and at a little distance from this tube there are air apertures, *a*, *a*, furnished with shutters in the inside, slanting from the top downward, to prevent as much as possible the escape outward of any vapor which may occasionally be carried down with the water from the condenser. The middle compartment, y^2, is perforated, convex at top, and concave at bottom; so that the water that drops from the tube *u*, in the convex top of y^2, falls off laterally through small pipes into the chamber y^2, while its concave bottom turns the water into a central filtering-box, *c*, that projects a little into y^3, set to receive it. For aerating this water, the bottom of y^2 is covered about an inch deep with small pebbles. y^3, which is the reservoir of the purified cool water, is perforated with small holes. c^1, c^1, are small pipes for promoting a continual upward flow of cold air. y^3 is furnished with a tap to draw off its water, as required.

For redistilling or rectifying spirituous liquids, the apparatus, *fig.* 501, is employed; in which the supply cistern A is much larger, and close at top; the upper condensing chambers, t^1, t^2, are also larger, but the lowest, t^3, is narrowed. The second rectifier of *fig.* 500, is removed. The feints collect in the bottom of the rectifier R, to be drawn off by a cock; while the rectified spirit passes off at top into the condenser. The refrigerator has only two compartments, and no pebbles. F is a funnel into which the spirits may be returned for redistillation.

For extracting the soluble matter of vegetable infusions, the apparatus, shown in *fig.* 502, is used. The rectifier is vertical, has a screw-capped hand-hold, *f*, for admitting the vegetables. g is a steam-pipe; and *h* is a funnel for returning portions of the liquid extract. R is connected by a pipe, *k*, with the condenser, T, made in two portions, fitted water-tight together, but separable for the purpose of cleansing. The steam which passes from the boiler into the rectifier R disengages the soluble portion of the vegetable substances, and if they be volatile, carries them off to the condenser; if not, it combines and falls with them to the bottom of the vessel, whence this portion of the extract is drawn off by the cock, and a fresh charge may be introduced. The steam is shut off from the rectifier R by a cock on pipe *g*. When the steam is afterward admitted to assist the process of maceration, the supply of it is regulated by the stop-cocks in the pipes *g* and *k*.—*Newton's Journal*, xxiii. p. 247, C. S.

In each experiment 1,840 lbs. weight were burnt, and the relative quantities of water evaporated show the relative economic effect. Two kinds of coal were used: Knowles's Clifton coal, a free burning kind which does not cake, and produces a considerable quantity of ashes; Barker and Evan's Oldham coal, a slow burning rich caking coal, yielding little ashes. The boiler was a 24-horse power, of Watt's waggon shape.

Mr. H. Houldsworth's Economy of Evaporation.

Weight of Charge.	Air.	Effect per Minute.		Water evaporated by		Average Temperature in the first Flue.	Economic Effect.	Effect as furnaces are usually worked, being asumed 100.
		Coals burnt.	Water evaporated.	1.840 lbs. of Coal.	1 lb. of Coal.			
Clifton coal:		*Lbs.*	*Galls.*	*Galls.*	*Lbs.*	*Degrees.*		
460 lbs. -	No air - - - - -	4·64	2·5	992	5·41	973	106	
460 lbs. -	45 square inches constant aperture - - -	4·68	3·21	1263	6·85	1165	135	
230 lbs. -	Air regulated partly by the eye, and partly by a scale, varying in some degree with the action of combustion -	4·43	3·09	1280	6·94	1122	136	
230 lbs. -	45 square inches - -	4·65	3·05	1210	6·6	1220	129	
230 lbs. -	No air - - - - -	4·43	2·3	942	5·12	995	100	
460 lbs. -	Air through two pipes 6 in. in diameter, each regulated by light - - -	4·65	3·13	1250	6·8	1160	134	
Oldham coal:								
230 lbs. -	No air - - - - -	3·67	2·65	1340	7·3	690	100	
230 lbs. -	35 square inches constant aperture - - -	4·05	2·76	1260	6·85	1080	94	
230 lbs. -	24 square inches constant aperture - - -	3·82	2·82	1360	7·4	1050	102	
460 & 230 lbs.	Air regulated by a scale -	3·84	2.94	1410	7.7	1070	106	
230 lbs. -	Air regulated so as to produce no smoke - -	3·61	2·87	1530	8·3	1053	114	
Hald Oldham, half Clifton -	- - - - - -	4.05	2·9	1320	7·2	1060		

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The average heat given in the first flue, as ascertained by a pyrometer and deduced from pyrometric diagrams. The air was admitted partly at the door and partly at the bridge; at the latter point through one of Mr. Williams's diffusion boxes, except in the last experiment with Clifton coal. They showed the effect of admitting air in greater or less quantity permanently or periodically by a uniform or varying aperture; and the general result arrived at is, that by the simple and inexpensive plan of admitting air into the furnaces at both the door and bridge by permanent apertures always open, varying in aggregate area from 1½ to 3 square inches (according to the quality of the coals) for every square foot of area of grate, an important saving in fuel is effected, and $\frac{9}{10}$ of the dense smoke prevented, without any special care of the fireman.

Deductions from the experiments on Clifton Coal:—

Gain in evaporation	by regulated admission of air -	- 35 per cent.
Do.	by 45 square inches constant aperture	- 34 „
Do.	by charges of 460 lbs. instead of 230 lbs.	- 4 „

Steam produced in a given time:—

No air -	- 230 lbs. charges -	- 100
No air -	- 460 lbs. do. -	- 109
53 square inches air	- 230 lbs. do. -	- 132
Air regulated -	- 230 lbs. do. -	- 134
53 square inches	- 460 lbs. do. -	- 140

showing that the admission of air increases the production of steam in a given time from 30 to 40 per cent.

EUDIOMETER, is the name of any apparatus subservient to the chemical examination of the atmospheric air. It means a *measure of purity*, but it is employed merely to determine the proportion of oxygen which it may contain. The explosive eudiometer, in which about two measures of hydrogen are introduced into a graduated glass tube, containing five measures of atmospheric air, and an electric spark is passed across the mixture, is the best of all eudiometers; and of these the syphon form, proposed by me in a paper published by the Royal Society of Edinburgh in 1819, is probably the surest and most convenient. Volta's explosive eudiometer, as made in Paris, costs 3 guineas; mine may be had nicely graduated for 6 or 8 shillings.

EXPANSION (Eng. and Fr.; *Ausdehnung*, Germ.) is the increase of bulk experienced by all bodies when heated, unless a change of chemical texture takes place, as in the case of clays in the potter's kiln. Table I. exhibits the linear expansion of several solids by an increase of temperature from 32° to 212° Fahr.; Table II. exhibits the expansion in bulk of certain liquids.

TABLE I.—*Linear Dilatation of Solids by Heat.*

Dimensions which a bar takes at 212°, whose length at 32° is 1·000000.

Substances	Authority.	Dilatation in Decimals.	Dilatation in Vulgar Fractions.
Glass tube - - - - -	Smeaton - -	1·00083333	
do. - - - - - - -	Roy - - -	1·00077615	
do. - - - -	Deluc's mean - -	1·00082800	
do. - - - - - - -	Dulong and Petit	1·00086130	$\frac{1}{1116}$
do. - - - - - - -	Lavoisier and Laplace	1·00081166	$\frac{1}{1148}$
Plate glass - - - - -	do. do.	1·000890890	$\frac{1}{1122}$
do. crown glass - - -	do. do.	1·00087572	$\frac{1}{1142}$
do. do. - - - -	do. do.	1·00089760	$\frac{1}{1114}$
do. do. - - - -	do. do.	1·00091751	$\frac{1}{1090}$
do. rod - - - - -	Roy - - -	1·00080787	
Deal - - - - - - -	Roy, as glass -	—	
Platina - - - - - -	Borda - - -	1·00085655	
do. - - - - - - -	Dulong and Petit	1·00088420	$\frac{1}{1131}$
do. - - - - - - -	Troughton - -	1·00099180	
do. and glass - - - -	Berthoud - -	1·00110000	
Palladium - - - - -	Wollaston - -	1·00100000	
Antimony - - - - - -	Smeaton - -	1·00108300	
Cast-iron prism - - -	Roy - - -	1·00110940	
Cast-iron - - - - - -	Lavoisier, by Dr Young	1·00111111	
Steel - - - - - -	Troughton - -	1·00118990	

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Substances.	Authority.	Dilatation in Decimals.	Dilatation in Vulgar Fractions.
Steel rod - - - - - -	Roy - - -	1·00114470	
Blistered Steel - - - - -	Phil. Trans. 1795, 428	1·00112500	
do. - - - - -	Smeaton - - -	1·00115000	
Steel not tempered - - -	Lavoisier and Laplace	1·00107875	$\frac{1}{927}$
do. do. - - -	do. do.	1·00107956	$\frac{1}{926}$
do. tempered yellow - - -	do. do.	1·00136900	
do. do. do. - -	do. do.	1·00138600	
do. do. do. at a higher heat	do. do.	1·00123956	$\frac{1}{807}$
Steel - - - - - - -	Troughton - -	1·00118980	
Hard Steel - - - - - -	Smeaton - - -	1·00122500	
Annealed steel - - - - -	Muschenbroek -	1·00122000	
Tempered steel - - - - -	do. - -	1·00137000	
Iron - - - - - - -	Borda - - -	1·00115600	
do. - - - - - - -	Smeaton - - -	1·00125800	
Soft iron, forged - - - - -	Lavoisier and Laplace	1·00122045	
Round iron, wire drawn - -	do. do.	1·00123504	
Iron wire - - - - - -	Troughton - -	1·00144010	
Iron - - - - - - -	Dulong and Petit	1·00118203	$\frac{1}{846}$
Bismuth - - - - - -	Smeaton - - -	1·00139200	
Annealed gold - - - - -	Muschenbroek -	1·00146000	
Gold - - - - - - -	Ellicot, by comparison	1·00150000	
do. procured by parting - -	Lavoisier and Laplace	1·00146606	$\frac{1}{682}$
do. Paris standard, unannealed -	do. do.	1·00155155	$\frac{1}{645}$
do. do. annealed -	do. do.	1·00151361	$\frac{1}{661}$
Copper - - - - - -	Muschenbroek -	1·0019100	
do. - - - - - -	Lavoisier and Laplace	1·00172244	$\frac{1}{581}$
do. - - - - - -	do. do.	1·00171222	$\frac{1}{584}$
do. - - - - - -	Troughton - -	1·00191880	
do. - - - - - -	Dulong and Petit -	1·00171821	$\frac{1}{582}$
Brass - - - - - -	Borda - - -	1·00178300	
do. - - - - - -	Lavoisier and Laplace	1·00186671	
do. - - - - - -	do. do.	1·00188971	
Brass scale, supposed from Hamburg	Roy - - -	1·00185540	
Cast brass - - - - - -	Smeaton - - -	1·00187500	
English plate-brass, in rod - -	Roy - - -	1·00189280	
do. do. in a trough form	do. - - -	1·00189490	
Brass - - - - - - -	Troughton - -	1·00191880	
Brass wire - - - - - -	Smeaton - - -	1·00193000	
Brass - - - - - - -	Muschenbroek -	1·00216000	
Copper 8, tin 1 - - - - -	Smeaton - - -	1·00181700	
Silver - - - - - - -	Herbert - - -	1·00189000	
do. - - - - - - -	Ellicot, by comparison	1·0021000	
do. - - - - - -	Muschenbroek -	1·00212000	
do. of cupel - - - - -	Lavoisier and Laplace	1·00190974	$\frac{1}{524}$
do. Paris standard - - - -	do. do.	1·00190868	$\frac{1}{524}$
Silver - - - - - -	Troughton - -	1·0020826	
Brass 16, tin 1 - - - - -	Smeaton - - -	1·00190800	
Speculum metal - - -	do. - - -	1·00193300	
Spelter solder; brass 2, zinc 1 -	do. - - -	1·00205800	
Malacca tin - - - - -	Lavoisier and Laplace	1·00193765	$\frac{1}{516}$
Tin from Falmouth - - - -	do. do.	1·00217298	$\frac{1}{462}$
Fine pewter - - - - -	Smeaton - - -	1·00228300	
Grain tin - - - - - -	do. - - -	1·00248300	
Tin - - - - - -	Muschenbroek -	1·00284000	
Soft solder; lead 2, tin 1 - -	Smeaton - - -	1·00250800	
Zinc 8, tin 1, a little hammered -	do. - - -	1·00269200	
Lead - - - - - - -	Lavoisier and Laplace	1·00284836	$\frac{1}{351}$
do. - - - - - - -	Smeaton - - -	1·00286700	
Zinc - - - - - - -	do. - - -	1·00294200	
Zinc, hammered out ½ inch per foot	do. - - -	1·00301100	
Glass, from 32° to 212° - -	Dulong and Petit -	1·00086130	$\frac{1}{1161}$
do. from 212° to 392° - -	do. do. -	1·00091827	$\frac{1}{1089}$
do. from 392° to 572° - -	do. do. -	1·000101114	$\frac{1}{987}$

The last two measurements by an air thermometer.

TABLE II.

Expansion of certain Liquids by being Heated from 32° to 212°.

Substances.	Authority.	Expansion in Decimals.	Expansion in Vulgar Fractions.
Mercury - - - - -	Dulong and Petit -	0·01801800	$\frac{1}{55\cdot5}$
do. in glass - - - -	do. do. -	0·01543200	$\frac{1}{65}$
Water, from its maximum density	Kirwan - -	0·04332	$\frac{1}{23}$
Muriatic acid (sp. gr. 1·137) -	Dalton - -	0·0600	$\frac{1}{17}$
Nitric acid (sp. gr. 1·40) - -	do. - -	0·1100	$\frac{1}{9}$
Sulphuric acid (sp. gr. 1·85) -	do. - -	0·0600	$\frac{1}{17}$
Alcohol (to its boiling point) ? -	do. - -	0·1100	$\frac{1}{9}$
Water - - - - -	do. - -	0·0460	$\frac{1}{22}$
Water, saturated with common salt	do. - -	0·0500	$\frac{1}{20}$
Sulphuric ether (to its boiling point) ?	do. - -	0·0700	$\frac{1}{14}$
Fixed oils - - - -	do. - -	0·0800	$\frac{1}{12\cdot5}$
Oil of turpentine - - - -	do. - -	0·0700	$\frac{1}{14}$

If the density of water at 39° be called - - - - 1·00000,
at 212° it becomes - - - - 0·9548,
and its volume has increased to - - 1·04734;
at 77° it becomes - - - - 0·9973587,
and its volume has increased to only - 1·00265,
which, though one fourth of the whole range of temperature, is only $\frac{1}{18}$ of the total expansion. Water at 60° F. has a specific gravity of - 0·9991953,
and has increased in volume from 39° to - 1·00008,
which is only about $\frac{1}{58}$ of the total expansion to 212°, with $\frac{1}{6\cdot4}$ of the total range of temperature.

All gases expand the same quantity by the same increase of temperature, which from 32° to 212° Fahr. $= \frac{180°}{480} = \frac{3}{8}$, or 100 volumes become 1·375. For each degree of Fahr. the expansion is $\frac{1}{480}$.

When dry air is saturated with moisture, its bulk increases, and its specific gravity diminishes, because aqueous vapor is less dense than air, at like temperatures.

The following table gives the multipliers to be employed for converting one volume of moist gas at the several temperatures into a volume of dry gas.

Temperature.	Multiplier.	Temperature.	Multiplier.
53° F.	0·9870	64°	0·9799
54	0·9864	65	0·9793
55	0·9858	66	0·9786
56	0·9852	67	0·9779
57	0·9846	68	0·9772
58	0·9839	69	0·9765
59	0·9833	70	0·9758
60	0·9827	71	0·9751
61	0·9820	72	0·9743
62	0·9813	73	0·9735
63	0·9806		

Expansion of certain Solids.	Absolute Dilatation.	Dilatation of a Metre.
Brass - - - - - - -	0·00187821	1·8782
Hammered iron - - - - -	0·00122043	1·2204
Carrara marble - - - - -	0·00084867	0·8486
Marble of St. Beat - - - - -	0·00041810	0·4181
Marble of Saht - - - - -	0·00056849	0·5685
Stone of Vernon on Seine - - - -	0·00043027	0·4303
Stone of St. Lew - - - - -	0·00064890	0·6489
Stone of Veilvie (volcanic) - - - -	0·00020390	0·2039
Alloy of D'Arcet - - - - -	0·00169688	1·6968
Bismuth - - - - - .	0·00121034	1·2103

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EXTRACTS. (*Extraits*, Fr.; *Extracten*, Germ.) The older apothecaries used this term to designate the product of the evaporation of any vegetable juice, infusion, or decoction; whether the latter two were made with water, alcohol, or ether; whence arose the distinction of aqueous, alcoholic, and etherous extracts.

Fourcroy made many researches upon these preparations, and supposed that they had all a common basis, which he called the *extractive* principle. But Chevreul and other chemists have since proved that this pretended principle is a heterogeneous and very variable compound. By the term *extract* therefore is now meant merely the whole of the soluble matters obtained from vegetables, reduced by careful evaporation to either a pasty or solid consistence. The watery extracts, which are those most commonly made, are as various as the vegetables which yield them; some containing chiefly sugar or gum in great abundance, and are therefore innocent or inert; while others contain very energetic impregnations. The conduct of the evaporating heat is the capital point in the preparation of extracts. They should be always prepared if possible from the juice of the fresh plant, by subjecting its leaves or other succulent part, to the action of a powerful screw or hydraulic press; and the evaporation should be effected by the warmth of a water bath, heated not beyond 100° or 120° F. Steam heat may perhaps be applied advantageously in some cases, where it is not likely to decompose any of the principles of the plant. But by far the best process for making extracts is in vacuo, upon the principles explained in the article Evaporation. It is much easier to fit up a proper apparatus of this kind, than most practical men imagine. The vacuum may either be made through the agency of steam, as there pointed out, or by means of an air-pump. One powerful air-pump may form and maintain a good vacuum under several receivers, placed upon the flat-ground flanges of so many basins, each provided with a stop-cock at its side for exhaustion. The air-less basin containing the juice being set on the shelf of a water-bath, and exposed to a proper temperature, will furnish in a short time a large quantity of medicinal extract, possessing the properties of the plant unimpaired.

For exceedingly delicate purposes, the concentration may be performed in the cold, by placing saucers filled with the expressed juice over a basin containing sulphuric acid, putting a glass receiver over them, and exhausting its air.

These preparations of vegetables for medicinal use are made either by evaporating the infusions of the dried plant in water, or in alcohol, or the expressed juice of the fresh plant; and this evaporation may be effected by a naked fire, a sand bath, an air bath, a steam heat, or a liquid *balneum* of any nature, all of which may be carried on either in the open air, or *in vacuo*. Of late years, since the vacuum-pan has been so successfully employed in concentrating syrups in sugar-houses, the same system has been adopted for making pharmaceutical extracts. An elegant apparatus of this kind invented by Mr. Barry, of Plough Court, was made the subject of a patent about 35 years ago. The use of the air-pump for evaporating such chemical substances as are readily injured by heat, has been very common since Professor Leslie's discovery of the efficacy of the combined influence of rarified air and an absorbing surface of sulphuric acid in evaporating water at low temperatures. It has been supposed that the virtues of narcotic plants in particular might be better obtained and preserved by evaporation in vacuo than otherwise, as the decomposing agency of heat and atmospheric oxygen would be thereby excluded. There is no doubt that extracts thus made from the expressed juices of fresh vegetables possess, for some time at least, the green aspect and odor of the plants in far greater perfection than those usually made in the air, with the aid of artificial heat. Dr. Meurer, in the *Archiv. der Pharmacie* for April, 1843, has endeavored to show that the color and odor are of no use in determining the value of extracts of narcotics, that the albumen left unchanged in the extracts made in vacuo tends to cause their spontaneous decomposition, and that the extracts made with the aid of alcohol, as is the practice in Germany, are more efficacious at first, and much less apt to be injured by keeping. M. Baldenius has, in the same number of the *Archiv.*, detailed experiments to prove that the juices of recent plants mixed with alcohol, in the homœopathic fashion, are very liable to spontaneous decomposition. To the above expressed juice, the Germans add the alcoholic tincture of the residuary vegetable matter, and evaporating both together, with filtration, prepare very powerful extracts.

F.

FAHLERZ. Gray copper-ore, called also Panabase, from the many oxides it contains.

FAINTS is the name of the impure spirit which comes over first and last in the distillation of whiskey; the former being called the *strong*, and the latter, which is much more abundant, the *weak* faints. This crude spirit is much impregnated with fœtid essential oil, is therefore very unwholesome, and must be purified by rectifications.

FAIRBAIRN'S TUBULAR BRIDGES. Of the tubular bridge system, the Conway and Menai are the first, and will probably for ever remain the most remarkable specimens, to attest the scientific genius of Mr. W. Fairbairn, their inventor and constructor. His claims, indeed, are exclusive and palpable. Mr. Robert Stephenson, however, has fortunately for himself, claimed the entire merit of having not only first conceived the idea of constructing a tubular bridge of such huge dimensions as to allow the passage of locomotive engines and railway trains through the interior of it, and of such length as to span distances of from 400 to 500 feet, but of having assured himself by laborious investigation and calculation of "the perfect feasibility of the work," without consulting any one else on the subject; and he has assigned to Mr. Fairbairn, in a very slighting fashion the place of a mere after adviser, of one who, in common with two other gentlemen (Mr. Eaton Hodgkinson and Mr. Edwin Clarke), but not more than either of them, assisted him in working out the construction which he "first broached." Mr. Fairbairn maintains, on the contrary, that the idea of a tubular bridge, though it unquestionably originated with Mr. Stephenson, was in his hands nothing more than a crude conception, very hesitatingly entertained, until he (Mr. Fairbairn) was called in to work it out, and that it has been wholly owing to his determined perseverance in the execution of the task confided to him, and to his numerous and elaborate experiments, that "the true principle on which tubular bridges should be constructed has been established, and thereby Mr. Stephenson's vague idea successfully carried into execution."

"At the period of the consultation in April, 1845, there were no drawings illustrative of the original idea of the bridge, nor had any calculations been made as to the strength, form, or proportions of the tube. I was asked whether such a design was practicable, and whether I could accomplish it: it was ultimately arranged that the subject should be investigated experimentally, to determine not only the value of Mr. Stephenson's original conception, but that of any other tubular form of bridge which might present itself in the prosecution of my researches. The matter was placed unreservedly in my hands; the entire conduct of the investigation was intrusted to me; and, as an experimenter, I was to be left free to exercise my own discretion in the investigation of whatever forms or conditions of the structure might appear to me best calculated to secure a safe passage across the Straits." (*W. Fairbairn's Correspondence.*)

In commenting on the treatise of Mr. Fairbairn "on the Construction of the Britannia and Conway Bridges," the editor of the Mechanics' Magazine says, "We have read it carefully, and not without strong prepossessions in favor of the inculpated party, but we feel honestly bound, however, to say, that the perusal has left us convinced, in spite of all leanings, that Mr. Fairbairn has not received at Mr. Stephenson's hands that justice to which he was entitled, but, on the contrary, has been treated most ungenerously and ungratefully. We will not say, that but for Mr. Fairbairn the tubular bridge idea would never have been carried out into practice, for that would be to assume that he engrossed in his single person all the practical skill of the country; but, looking into the facts of the case as they stand, and as we see them established in the volume before us beyond all possibility of dispute, we hesitate not to affirm, that it is more owing to Mr. Fairbairn, than to any one other individual whatever, not excepting Mr. Stephenson himself, that it is now the triumphant reality which it is. Another might possibly have done the part which fell to the lot of Mr. Fairbairn as well, but none could possibly have done it better. He conceived and directed all the preliminary experiments,—all at least with an exception or two, which were of any practical value, exhibiting therein a combination of philosophical painstaking with mechanical skill and ingenuity, such as is not often witnessed; he finally settled the form which it was best to give to the tube, and arranged the whole of the executive details; he personally superintended the construction of the Conway Bridge, which our readers are aware is but the Menai or Britannia Bridge on a smaller scale; and he only retired from further co-operation with Mr. Stephenson in the affair when nothing new was left to be discovered or achieved. The motives for his retirement are thus very fairly and temperately stated:—

"'I have now brought down this correspondence to the period when my official connection with the Chester and Holyhead Railway Company as engineer, for the construction of the tubular bridges, may be said to have virtually ceased, and I should willingly have passed over in silence the remainder of the events which transpired, were it not that the completeness of the narrative, as well as the justification of my conduct, demanded some explanation, independently of the regret which I experienced in withdrawing from an undertaking to which I had devoted so much time and thought,—an undertaking fraught with the greatest interest, and which had, as it were, grown up in all its magnificent proportions under my own directions. I can truly say that the disagreement which took place with Mr. Stephenson is on my part much deplored. But I trust that the reader of the foregoing pages will at least have arrived at the conclusion, that I had taken the most important part in developing, and giving a practical form to Mr. Stephenson's idea, and also in the superintending the construction and erection of the first Conway tube. The fact is, I labored almost incessantly in devising plans, or in watching over the practical details of the work, from the day in which Mr. Stephenson's suggestion was communicated to me until the close of my engagement; and I can sincerely say that I was always actuated by the principle of leaving nothing undone which could in any way contribute to the successful accomplishment of the undertaking. Regardless of the prognostications of failure with which the scheme was assailed, and in despite of the opposition of those whose assistance I had solicited, I uniformly advocated the peculiar principle on which the Conway Bridge has been constructed.

"'Such being my position, and viewing the extent of services I had rendered, it will, I think, be generally allowed that it was very natural that I should desire to have my name publicly associated with Mr. Stephenson's as joint engineer for these bridges. Indeed, it may very fairly be said that I might have ventured to claim this distinction, since it had been conferred upon me by the Board of Directors on Mr. Stephenson's own recommendation. If, instead of success having crowned our efforts, failure had unfortunately ensued, would not my reputation have suffered as well as Mr. Stephenson's? The working plans having gone forth with my name alone attached to them, and from my being recognised as the acting engineer, might not the whole blame have been conveniently thrown on me in case of failure?

"'It was not, however, on any of these grounds that I was induced to resign my appointment, for there had not then occurred any opportunity where I conceived it necessary to have my position publicly recognised; and I had always believed that, when the proper time came, Mr. Stephenson would be the first to establish that position, and acknowledge the services I had rendered. The recognition was, however, very shortly afterwards denied me. The first Conway tube having been completed, and the success of the principle established, I conceived that the construction of the remaining tubes simply required a close attention to the system of construction already adopted, and therefore might safely be entrusted to those gentlemen whose constant presence during the building of the first tube had rendered them thoroughly acquainted with the whole details of the work. By such an arrangement, moreover, the Company would save the amount which had hitherto been paid for my services, and I should be enabled to devote my time to other pursuits which I had neglected for this work, and which now urgently demanded my attention. This was one reason for my retirement; but what chiefly led me to this decision, was the position assumed by Mr. Stephenson, his public misrepresentation of the position I held under the Company, and his endeavor to recognise my services as the labors of an assistant under his control, and acting entirely under his direction. Had Mr. Stephenson in his public address done me the justice to state my independent claim to some of the most important principles observed in the construction of the tubes, I might, perhaps, have continued my services until the final completion of the whole undertaking; and, most assuredly, this work would never have come before the public. I now appeal to the preceding pages of this narrative, whether Mr. Stephenson's assertions are borne out by the simple statement of facts? I have overstated nothing, concealed nothing; and the reader is left to draw his own conclusions from these facts, after having become acquainted with the course pursued by Mr. Stephenson, which I will in conclusion concisely relate.' (p. 171.)

"Mr. Fairbairn proceeds then to give an account of a public dinner to celebrate the completion of the Conway Bridge, which took place on the 17th of May, 1848; on which occasion it was, Mr. Stephenson first openly assumed that position in regard to Mr. Fairbairn and the undertaking, which has made the present appeal to public justice necessary. Mr. Stephenson's speech was confessedly a studied affair—he had announced beforehand that he would avail himself of the opportunity of 'setting the question at rest;' but for all that it does not take Mr. Fairbairn many words to demolish it utterly.

'The inaccuracies, both as to facts and dates, in the statements of Mr. Stephenson, are very numerous. It simply requires a reference to the short description of the Ware Bridge, and to the drawings, to disprove the assertion, that it is a thin tubular bridge, although not precisely the same as the present, yet in principle precisely the same; and it can easily be shown too, that considering the Ware Bridge as a simple girder bridge, it is exceedingly defective in design. Is there anything new in this application of wrought-iron plate girders? As well might it be said that the combination of wrought-iron deck beams, so many years applied in iron ships for the support of the decks, is a "counterpart of the proposed cellular top for the Britannia tubes." I really cannot but regret that Mr. Stephenson, whose name will be always associated with the grandest bridge that has ever been constructed, should have committed himself in making such an erroneous assertion as that it was by reviving and extending his original conception of this imperfect structure at Ware, that he was led to originate the bridges crossing the Conway and Menai Straits.

"'Mr. Stephenson's remarks further admit of the disingenuous construction that his scheme was matured before the Bill for the Chester and Holyhead Railway was passed by Parliament, and before I was consulted, and that he was at that early period acquainted with the present design of the bridge. He refers to the incredulous glances which were directed towards him when the description of the bridge was explained to the Committee; and intimates,* "that it was not until the Bill had been obtained, and it became necessary to commence, that he requested my assistance." Now, my advice was asked by Mr. Stephenson before his evidence to the Parliamentary Committee was given, and he announced his idea to that Committee strengthened by more than one opinion of its feasibility. Let the reader turn again to the earlier letters of the correspondence, and he will find of what a crude and dangerous scheme that idea consisted; how totally dissimilar in form and principle it was to the present tubular structures, and how slowly Mr. Stephenson was persuaded to give up his earliest conceptions. Again; Mr. Stephenson states that he called in the aid of Mr. Hodgkinson and myself at the same time; now it is essential to the proof of my claims that this assertion should be explicitly contradicted. It was I, and not Mr. Stephenson, who solicited Mr. Hodgkinson's co-operation, and this was not done until I had been actively engaged for several months in my experimental researches, and after I had discovered the principle of strength which was offered in the cellular top, and not only proved the impracticability of Mr. Stephenson's original conception, but had given the outline of that form of tube which was ultimately carried into execution.

"'When Mr. Stephenson had made up his mind to claim in the manner he did the whole merit of the undertaking, it is not difficult to understand his reason for giving Mr. Clarke, his own assistant, so prominent a position. I willingly bear my testimony to the great value of the services rendered by Mr. Clarke, to his talents, and to the great energy which he displayed in working out his several duties, but these had no reference whatever to the designing of the structures.' (p. 178.)

"There is one part of the case on which we think Mr. Fairbairn does not insist enough, though, in our judgment, it is of itself decisive of the inordinateness of Mr. Stephenson's pretensions. Mr. Stephenson and his friends, for obvious reasons, slur it over altogether. We refer to Mr. Fairbairn's appointment to be joint engineer along with Mr. Stephenson to the Conway and Britannia Bridges. The evidence of this is a Minute of the Board of Directors of the Chester and Holyhead Railway, dated 13th May, 1846, which we here quote at length from the work before us.

"'Resolved—1st. That Mr. Fairbairn be appointed to superintend the construction and erection of the Conway and Britannia Bridges, in conjunction with Mr. Stephenson.

"'2d. That Mr. Fairbairn have, with Mr. Stephenson, the appointment of such persons as are necessary, subject to the powers of their dismissal by the Directors.

"'3d. That Mr. Fairbairn furnish a list of the persons he requires, with the salaries he proposes for all foremen or others above the class of workmen.

"'4th. That advances of money be made on Mr. Fairbairn's requisition and certificates, which, with the accounts, or vouchers, are to be furnished monthly.

"'5th. That the Directors appoint a bookkeeper at each spot, the Conway and the Menai.'

"To talk, after this, of Mr. Fairbairn's being only entitled to a secondary and subordinate place in the affair, is to outrage all truth and propriety.

"We can but regard with profound pity the hallucination which has betrayed a man of Mr. Stephenson's genius and worth (this unfortunate episode notwithstanding) into so false a position.

"We do not overlook that we have as yet Mr. Fairbairn's statement of the case only, and that we may expect to see, ere long, something of a very opposite complexion from Mr. Stephenson or some of his friends. We shall give all due consideration to any such counter-statement when it comes before us; but so well is all Mr. Fairbairn says borne out by written, and therefore unalterable proofs, that we do not, in the meanwhile, hesitate to avow our firm belief that nothing which can possibly be adduced in the way of either evidence or argument, can ever alter materially the conclusion at which we have already arrived."—*Mechanic's Magazine.*)

Fairbairn's Tubular Girder Bridges.—William Fairbairn, Esq., of Manchester F. R. S., and Member of the Institute of France, has been long recognised as the most accomplished of our factory engineers and the most skilful of our millwrights, by his

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admirable fire-proof buildings and his magnificent hydraulic machines. Having a few years ago directed his constructive genius to the building of iron steam-ships, he became thereby well acquainted with the prodigious stiffness and strength of which hollow girders of thin sheet iron were susceptible. He was naturally pitched upon by Mr. Stephenson, the engineer of the Chester and Holyhead Railway, as the fittest person to execute the tubular bridge which was regarded by him as the only means of carrying ponderous railway trains over the tremendous sea-gulf of Menai's Straits or Conway's roaring flood. The tidal torrents of these two places being deep and rapid, required to be crossed by bridges of extraordinary span and strength. No centrings or other substructures usually resorted to for mounting such huge pontitectures could be erected. In such a dilemma, the most obvious resource of the engineer was a suspension bridge; but the failure of more than one attempt of that kind had proved the impossibility of running railway trains over such bridges with safety.

Under Mr. Stephenson's direction, numerous other schemes had been devised. Both timber and cast-iron arches had been thought of; and a model of a very handsome bridge for crossing the Menai Straits on the latter principle had been constructed, and submitted to the consideration of a parliamentary committee. The possibility of throwing cast-iron arches over so great a span as 450 ft. was however questionable; and the security of such a bridge must have been endangered by the great changes which the material would have been subjected to from atmospheric influences, and from vibrations produced by the passage of heavy trains. But a more important objection even than these caused the withdrawal of this design. The Lords Commissioners of the Admiralty, as conservators of the navigation, opposed the erection of any structure which should offer a hindrance to the free passage of vessels under it, and insisted on a clear headway of 105 ft. from the level of high water. Mr. Stephenson then conceived the original idea of a huge tubular bridge, to be constructed of riveted plates, and supported by chains,* and of such dimensions as to allow of the passage of locomotive engines and railway trains through the interior of it. The illustrious Galileo, in demonstrating the strength of tubular structures, adverted to the quills of birds and the stalks of corn; but in our days we see that idea amplified into colossal dimensions.

It was with reference to this expedient, after all others had been found inapplicable, that Mr. Fairbairn was consulted by him, and requested to give his opinion—first, as to the practicability of the scheme; and secondly, as to the means necessary for carrying it out. The consultation took place early in April, 1845. Mr. Stephenson conceived that the tube should be either of a circular or egg-shaped sectional form; and he was strongly impressed with the primary importance of the use of chains, placing his reliance in them as the principal support of the bridge. He never for a moment entertained the idea of making the tube self-supporting. The wrought-iron tube, according to his idea, was indeed entirely subservient to the chains, and intended to operate from its rigidity and weight as a stiffener, and to prevent, or at least to some extent counteract, the catenary principle of construction.

" February 23d, 1846.

"My dear Sir,

"I have been considering the principle on which you purpose attaching the chain for the support of the tube; and with every deference to your judgment, I am almost inclined to differ with you upon that point.

"It appears to me that the great and important consideration is to relieve the strain upon the tube. It is quite clear that a series of chains on each side of the plates, well fitted and tightly screwed up, would tend to stiffen the sides, and give greater rigidity to these parts. This is, however, not what is wanted. *The rigidity is required on the top side;* as in all the experiments the sides seldom get out of form unless distorted by the crushing of the top side. Under these circumstances the stiffening should in my opinion be on the top platform of the tube."—*William Fairbairn to Mr. Robert Stephenson.*†

For many months afterwards, and even up to the time of the experiments on the model tube in December 1846, Mr. Stephenson insisted on the application of such chains. "I always felt," says Mr. Fairbairn, "that in a combination of two bodies, the one of a perfectly rigid, and the other of a flexible nature, there was a principle of weakness; for the vibrations to which the one would be subjected, would call into operation forces whose constant action upon the rivets and fastenings of the other could not but tend to loosen them, and thus, by a slow but sure agency, to break up the bridge."

In consequence of the favorable opinion entertained by Mr. Stephenson on the cylindrical tubes, it was deemed expedient to commence experiments upon models of that kind, and to extend them subsequently to elliptical tubes. Experiments carefully made, demonstrated the weakness of these two forms, and the vastly greater strength of the rectangular tubes, which were accordingly adopted with cellular top and bottom.

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* These chains, not only superfluous but dangerous, would have cost 150,000*l.*

† Conway and Menai Bridges, by W. Fairbairn, C. E., p. 48.

In Mr. Stephenson's examination before the Select Committee of Railways of the House of Commons, 5th and 6th of May, 1845, he says: "I am instituting a series of experiments in conjunction with Mr. Fairbairn of Manchester, who is already in possession of experiments on iron ships, which place the thing beyond all doubt. He has ascertained that a vessel of 250 ft. in length supported at the ends will not yield with all the machinery in the middle.

"Have your calculations been submitted to any other engineers?

"*I have made them, in conjunction with Mr. Fairbairn of Manchester, whose experience is greater than any other man's in England.* There is an iron vessel now building by Mr. Fairbairn 220 ft. in length; and he says that he will engage, that, when it is finished, it shall be put down on the stocks at each end, and shall have 1000 tons of machinery in the middle of it, and it will not affect it. But that is not so strong as a tube, and therefore, any experiment that this would carry out, the tube would fully bear."

The floating of the first Conway tube—"The transport of a huge mass of iron 412 ft. long, 25 ft. 6 in. high, 15 ft. wide, and weighing not less than 1300 tons, was a task of no ordinary difficulty. No former effort with which we are acquainted can, I think, be said to have equalled it, when the unwieldiness of its form, and the extraordinary natural difficulties to be encountered, are taken into consideration. Many of the works of the ancients are stupendous in conception and colossal in dimensions; and it has been a constant matter of inquiry, in what manner a people, ignorant of the mechanical appliances which we possess, could raise structures which have resisted all the inroads of time, and which are to the present generation objects of awe and admiration. In more recent times, the transport of the immense granite block which forms the base of the statue of Peter the Great at St. Petersburg, was looked upon as a most extraordinary achievement; but it cannot he said to have been so formidable an undertaking as the moving of the Conway tube. The granite block was a compact mass, being 42 ft. at the base, 21 ft. thick, and 17 ft. high, and capable of being moved on rollers, &c., to the raft which carried it down the Neva to the site of the city; but in the case of the Conway tube, after the most anxious consideration, and when numerous schemes and proposals had been weighed, examined, and rejected, that of floating the mass on pontoons or barges was decided upon as the most feasible and most secure, the centre of gravity being in this case, necessarily raised several feet. In addition to this disadvantage, the whole had to be handled and manœuvred in probably the most difficult tideway in Europe, where the current rushes through a narrow gorge of great depth to fill the broad expanse of the inland bay, at a rate of 6 or 7 miles an hour; and the utmost nicety had moreover to be observed in bringing the tube to its place, as there was only a clearance of 12 inches; that is, the distance between the opposite masses of masonry was only 12 inches greater than the length of the tube. All these obstacles may well be termed formidable; and I therefore conceive that the utmost praise is due to Mr. Stephenson for the admirable arrangements and contrivances which rendered the first attempt at so gigantic an operation perfectly successful."

I have quoted these liberal remarks of Mr. Fairbairn in proof of his good feeling towards the engineer associated with him conformably to the Minute of the directors of the Chester and Holyhead Railway, of date May 13, 1846, already quoted.

How defective, and even erroneous, Mr. Stephenson's conceptions were of the tubular girder construction so late as the 26th October, 1846, appears, from his stating in a letter of that date addressed to Mr. Fairbairn, "that this was not the first time he had the idea of employing wrought-iron tubular bridges; for three years ago, or thereabouts, I had erected at Ware, on the Northern and Eastern Railway, a cellular platform of wrought-iron. It was, in fact, I believe, a counterpart of the proposed top of the Britannia bridge."

"As this statement," says Mr. Fairbairn, "has been frequently repeated since the letter was written, I feel myself called upon to show that Mr. Stephenson has no claim to originality in this bridge, and that it has no resemblance whatever, either in principle or construction, to the Conway or Britannia tubes. On the contrary, the bridge in question is constructed upon the principle of the common cast-iron girder bridge, each separate beam being formed of wrought-iron plates connected together by angle irons. This form of wrought-iron girder had been long in use before the erection of the Ware Bridge; and it is defective as well in principle as in construction; the great body of the material is not in the top flanches, as it ought to be, in order to attain the section of greatest strength. In Experiments 14, 15, and 16 (see Appendix and p. 10 in the Report), it is clearly shown that the top flanche of a wrought-iron girder, if made solid, should be more than twice the area of the bottom flanche. Now it appears that the top flanche in the said bridge at Ware is to the bottom flanche as 4 to 15 nearly; an exceedingly defective structure. If this beam were turned upside down it would carry more than double the weight. From the defective principle upon which the bridge is constructed, it is evident that Mr. Stephenson was not then acquainted with the proper form of wrought-iron girder bridges. Nor is this surprising, as no experimental facts were at that time in existence to show the difference between the two resisting forces of compression and extension of wrought-iron beams."—*Conway and Britannia Bridges, by Mr. Fairbairn*, pp. 113, 114.

"It is impossible to trace any analogy between a combination of this form of beam and a tubular girder with a *cellular top.* The beams in the Ware Bridge do not offer a united resistance to strain in the manner which beams with a cellular structure do; on the contrary, each beam has its distinct part of the load to carry, and that imperfectly, for want of a due proportion in the top and bottom flanches."—*Ibidem.*

A striking proof of the accuracy of Mr. Fairbairn is afforded by the fact, that it was not till the latter part of 1846, that Mr. Stephenson finally made up his mind to abandon the use of the chains, for in the engravings of both the Conway and Britannia Bridges, which were published in that year, there is attached to them the name of Robert Stephenson, Esq., engineer. These drawings represent, with tolerable accuracy, the proportions and forms of the tubes of both bridges as they now exist,—viz., the long, low, rectangular galleries, which Mr. Fairbairn's experiments had shown to be much better adapted to the purpose than the elliptical tubes proposed by Mr. Stephenson. But mark, *in both cases the chains are absolutely shown attached to the tubes.* They are a prominent feature in the drawing, and therefore conclusive evidence that up to that time at least, and notwithstanding the discovery of the increased strength and security to be derived from the adoption of the tube with a rectangular section and the distribution of the material on the top side in the form of cells, Mr. Stephenson still thought the auxiliary support indispensable.

From the moment that Mr. Fairbairn commenced this experimental investigation, the whole matter, as regarded the development of the best form of the tubes, was unreservedly in his own hands. Mr. Stephenson was not present at the experiments, he neither superintended nor directed them, but was simply made acquainted with results, and approved, when completed, what Mr. Fairbairn did. And now what did Mr. Fairbairn's experiments show? They first of all confirmed his own early opinion, that the security of the bridge, if built at all, must depend solely upon the self-contained strength of the tube, and that the application of any form of catenary would introduce into the structure an agency of a destructive tendency. They proved the weakness and total inadequacy of either of the sectional forms of tubes (cylindrical or elliptical), thought of by Mr. Stephenson. They led Mr. Fairbairn, after carefully observing all the signs and symptoms of weakness shown by the models when under strain, to recommend, as a stronger form of tube one having a rectangular section. They brought to light some curious and anomalous appearances exhibited by wrought-iron when subjected to a crushing force. They showed that tubes of a uniform distribution of material, when loaded with an increasing weight, first yielded on the upper side; and this *fact*, therefore, induced Mr. Fairbairn, first, to thicken the material in that part, and, subsequently, led him to suggest that distribution of the material in the form of hollow cells or tubes, wherein lies the secret of the strength of this system of tubular construction.

Mr. Fairbairn therefore, reasoning from his experiments,—1st, suggested the rectangular sections for the tubes; 2d, discovered that important and beautiful element of strength and lightness, the cellular arrangement of the top; and 3d, was mainly instrumental in causing the final abandonment of chains.

Beyond this, after he was appointed engineer with Mr. Stephenson for the structure, he worked out the detail of the tubes, had the whole of the *working drawings* for the tubes of both bridges made at his own office, and under his constant supervision, proportioned the different parts, and (again the result of reasoning from experiment) suggested that admirable system of chain riveting which is adopted in those parts of the tubes liable to a tensile strain, and which adds in a material degree to the strength of the structure.

A bridge with several spans of nearly 500 feet each was wanted, which should not only be unyielding with its own necessarily enormous weight, but which should possess within itself such an excess of strength as would satisfy an incredulous public that it would be abundantly safe when subjected to the shocks and vibrations of a heavy locomotive engine with its accompanying train passing across it at a speed of forty miles an hour. The situations both at Conway and the Straits afford obstacles of extraordinary magnitude: at both places the estuaries were of great depth, defying the use of scaffold ing to assist in the erection of the bridges, and the tides washed through with appalling impetuosity. The Menai or Britannia Bridge was moreover to stretch from shore to shore at a giddy height of more than 100 feet from the level of high water, and, as if to render insuperable the obstacles which Nature had raised to the progress of the engineers work, an arbitrary but absolute order was issued from the controllers of the navigation that the whole was to be accomplished without hindrance or obstruction to the rights which they guarded. The manner in which all these necessities were complied with is well known. The Britannia and Conway Bridges exist, the pride of the country which possesses them, triumphs of the constructive arts, and immortal monuments to the men who were associated in their contrivance and execution. It is to be deplored in every respect that jealousies and rivalries should have arisen under circumstances where so much renown and merit was to be divided. The grandeur and boldness of the conception was Robert Stephenson's, but the merits of the existing structure, the ingenuity of the arrangement, and proportions of the material,—the discovery, in fact, of the tubular principles of construction,—are William Fairbairn's.

As an outgrowth of the remarkable introductory experiments made in connection with these wonders of North Wales, we must regard the equally important, though less imposing tubular girder system; the new and scientific discovery of great advantages to be derived from a peculiar combination of material, applied to the simple and generally used beam or girder. A tubular girder, as the name implies, is a hollow beam constructed of metal plates firmly riveted or fastened together. When subjected to a transverse strain or load tending to break it, the law, which is applicable to every body, be it solid or hollow, is observable. The parts of the girder above the neutral axis have to arrange themselves to a resistance of a compressive strain, while those below that line are violently subjected to a force tending to draw them asunder. The extreme difficulty of wrought-iron and its great power to resist tension, were well known, and in the earlier stages of the inquiry it was considered feasible, and frequent efforts were made to arrange the parts in such manner that these known properties might be taken advantage of in both the upper and lower sides of the girder, but every experiment baffled the ingenuity of the contrivance, and nature soon taught the constructor that her unerring laws were not to be disregarded. This point being established, viz., that no distribution of the metal in a tubular girder could change the character of the forces which would act upon it, Mr. Fairbairn's great merit lies in the ingenuity with which he adapted his new material to those strains. In the top or upper side of the girder he distributed it, in that beautiful cellular form which imparts the real strength and security to the structure, and in the bottom he connected the parts by an ingenious system of fastening which assimilated the strength of the joints with that of the solid plate.

The description of one of the best constructed tubular girders will give the most correct idea of their power and peculiarity. We select for illustration the beautiful bridge erected across the Trent at Gainsborough. *Fig.* 503 represents a general elevation of the bridge which carries the Lincolnshire railway across the Trent. Its total length is 332 feet, the two main spans being 154 feet each. The width of roadway between the two main girders is 26 feet, giving ample room for a double line of railway. The width of the centre pier is 12 feet, and the tubular girders have a bearing on each land abutment of 6 feet. *Fig* 504 represents a cross section form of the main girders, and to this we must direct especial attention in order to make the peculiarities of the system well understood. The height of each girder from end to end is 12 feet; this parallelism is not the best form to give a maximum resistance with a minimum amount of material; but from the greater facilities of construction is preferable to the parabolic form, and practically the proportions of the strength may be adjusted by varying the thicknesses, instead of the linear dimensions of the parts.

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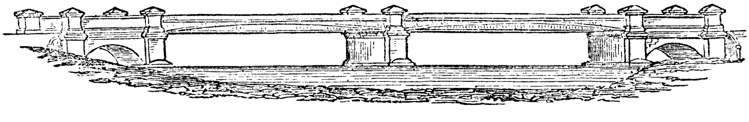
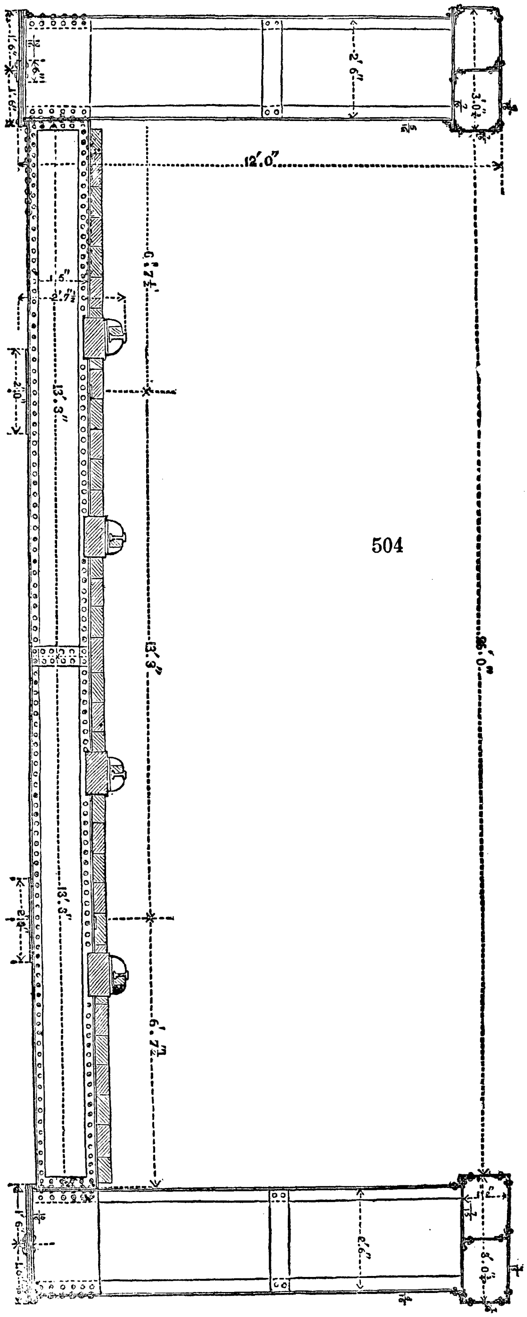


The Bottom of the Girder.—The bottom is framed of double thicknesses of long rolled plates, connected together in the manner hereafter described. Being subjected solely to a tensile strain, the material is condensed as much as possible, so as to assimilate that part of the structure to one unbroken solid sheet, which, if practicable, would be the best distribution of form. Each plate is 12 feet long by 18 inches wide, varying in thickness according to its position from the centre line of each span, where the greatest



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amount of material is accumulated. The bottom is necessarily connected to the sides of the girder by long bars of heavy L or angle iron, firmly riveted to both.

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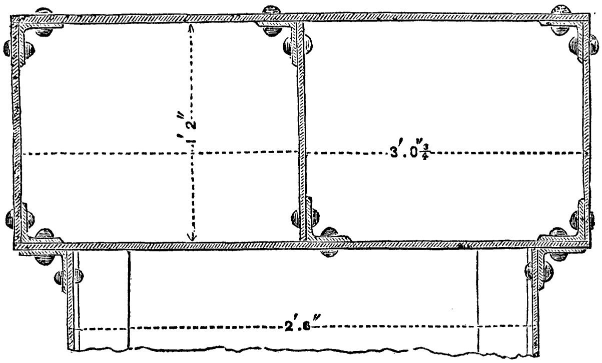
The Sides of the Girder.—The side plates are 2 feet wide throughout, and of uniform thickness, excepting in the immediate neighborhood of the piers and abutments, where they are strengthened and stiffened by pillars of strong T iron, to offer a due resistance to the dead weight of the girder itself. The joints are made with external covering plates 4½ inches wide, and internal ribs of T iron, which suffice to keep the side plates rigid, and enable them to accomplish their duty of separating the top and bottom of the girder.

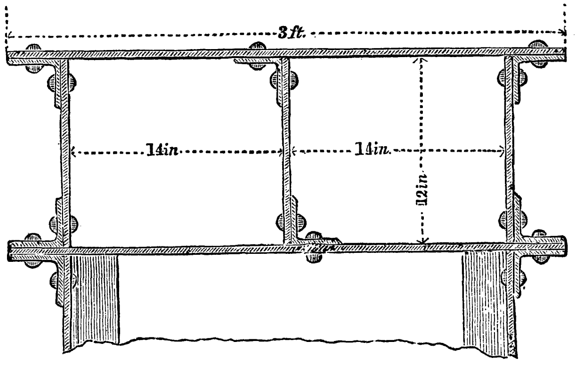
The Top of the Girder.—In this part the principal novelty and ingenuity are observable. A single sheet of iron, like a sheet of paper is easily put out of shape by a compressive strain. It crumples up, and at once loses all power of resistance. A sheet of common writing paper, which when placed on edge will nearly support itself, when rolled into a cylinder, say of 1 inch diameter, will carry a considerable weight. In the same manner a given sectional area of plate, if placed in that simple form in the top of the Trent girder, would crumple up with a comparatively small weight, but when distributed according to Mr. Fairbairn's tubular arrangement it offers extraordinary resistance to compression.

505



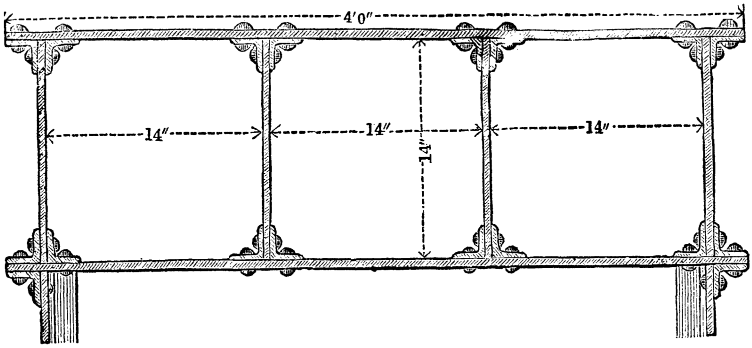
The value of this arrangement will be understood when it is stated that notwithstanding the superior tenacity of wrought-iron, a well constructed tubular girder only requires an excess of sectional area in the top over the bottom of $\frac{1}{12}$. In the Trent girder (see *fig.* 504), the top compartment is 3 feet ¾ inch wide, and 15 inches deep, divided by a vertical plate into two rectangular cells, and all firmly connected by rivets, and L iron. Those angle irons constitute important elements in its strength. Since the construction of the Trent bridge, the cost of construction of tubular girders has been much diminished by a different arrangement of the parts of the top compartment, as shown in the following, *fig.* 506. This form is equally powerful in its resistance. When the span of the bridge reaches 180 or 200 feet, the top compartment is arranged as shown in *fig.* 507, and when it is under 60 feet as shown in *fig.* 508. It will be noticed that in every case the

506



cells are proportioned, so as to admit of the entrance of a man for the purposes of painting or repairs.

507



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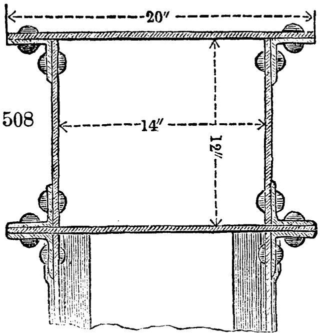

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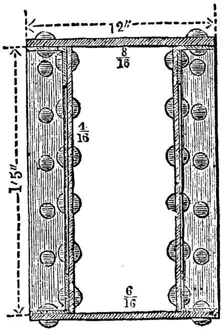
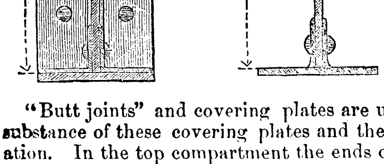


The Cross Beams or Supports of the Roadway.—These are generally, and ought to be universally, made of iron. In the Trent bridge they are made hollow or box beams, as shown in the annexed figure, *fig.* 509. Their construction is now much simpler and equally good, thus *fig.* 510.

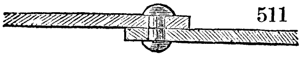
510



The Riveting.—Upon the judicious fastenings of the plates together depends in a great measure the safety of a tubular girder bridge. The system of riveting followed in the several parts should have reference to the strains which occur in those parts. What are technically called "lap joints," where the ends of the plate overlap each other, and are connected by a single row of rivets, (vide *fig.* 511,) should be avoided in every part of the structure, as they have been proved to be weak and insufficient. Mr. Fairbairn (*Phil. Trans.* part ii. 1852) gives the value of single and double riveted joints, as 70 and 56 respectively, the solid plate being assumed to be 100.

"Butt joints" and covering plates are used throughout the girder, the length and substance of these covering plates and the number of rivets varying according to situation. In the top compartment the ends of the plates having been carefully fitted to each other, so as to take their portion of the strain the moment the load is applied, are covered by strips of sufficient width to receive a double row of rivets, one on each side of the joint, thus, as shown in *fig.* 512. This arrangement effectually prevents some such effect as indicated in *fig.* 513, which would occur were the lap joint used, and the load very great. In the tops the rivets are generally spaced 3 inches apart from centre to centre.

As before mentioned, instead of simple strips covering the vertical joints of the side plates, inside T iron bars are used to afford stiffness, and prevent the approach of the top and bottom (vide *fig.* 514.) Thus, the rivets being spaced 3 inches, the strips give to the external elevation of the girder the appearance of a series of panels.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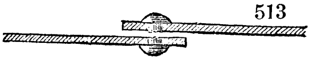
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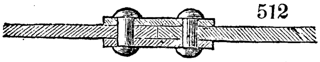
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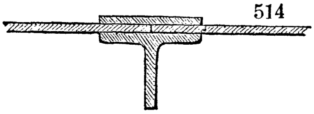
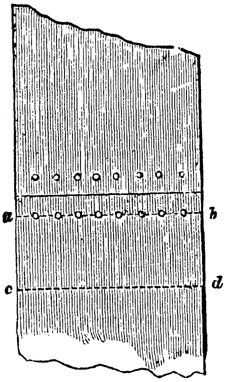

514

In the bottom an exceedingly ingenious and beautiful arrangement of riveting has been introduced by Mr. Fairbairn. It is evident that to join two plates together (these two plates having to resist a force tending constantly to separate them) a certain number of rivets or pins are required, and according to the old system of jointing, these rivets were placed in single rows along the edge of the plates, being in fact either single lap joints, or single butt joints. Suppose the plates in *fig.* 515 to be each 2 feet wide, and ½ inch thick, and that to connect them there were wanted 16 rivets, each 1 inch diameter. It is evident the resisting powers of the plates are weakened exactly by the amount of material punched out, in this case one-third, the section of resistance being through the line *a b*, and not through the line *c d.* But if these 16 rivets, instead of being placed all parallel with the joint, are arranged as shown in *fig.* 516 and covered with long "covering plates" instead of "strips," it is equally evident that they are in this position equally fitted to their duty of joining the plates and that the punching has weakened the resting powers of the plates only $\frac{1}{12}$ instead of ⅓. These proportions will readily explain the saving in material and weight which Mr. Fairbairn's "chain riveting" has effected, and the following figure of the "bottom" of the Trent bridge will show how it is practically applied (*fig.* 517.) The joints of the angle irons in the bottom are also jointed by long corner pieces, as may be noticed at *a*, in *fig.* 518, which is a view of a short length of the bottom of the main Trent girder. Having thus described the tubular girder bridge in its best and most generally adopted form, a glance at the following figures (*figs.* 519, 520) will indicate modifications of the system which have gained favor in some quarters.

515



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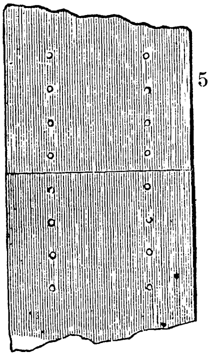

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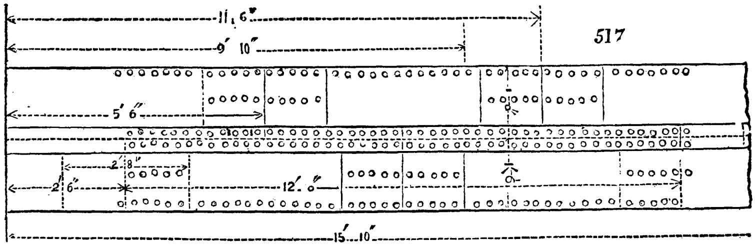

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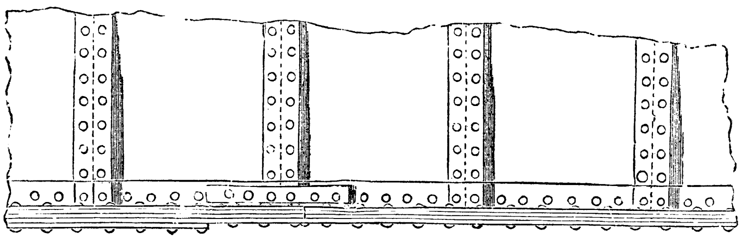

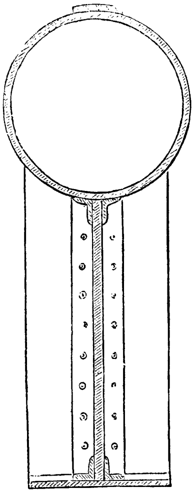

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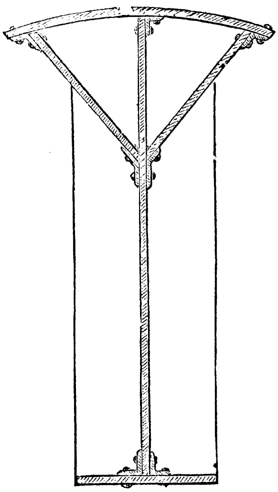

The Proportions and Strength of Tubular Girders.—The limits of this article will not admit of a lengthened examination of these interesting topics. A well proportioned beam or girder should have such a sectional distribution of its material, that when subjected to a transverse strain, the top should yield to compression and the bottom to extension at one and the same time; and as nearly all materials offer unequal resistances to the two forces, direct experiment can alone determine the exact relative proportions of the two parts. Thus, the resisting power of cast-iron to compression is nearly six times greater than that which it offers to extension; but Mr. Fairbairn's ingenious distribution of the wrought-iron plates in the "cellular top" has enabled him to fix the relative sectional areas of the tops and bottoms of tubular beams in the ratio of 12 to 11.

The tables of the following page show the proportions for tubular girder bridges of spans from 30 up to 300 feet.

Mr. Fairbairn's formula for calculating the strength of tubular girder bridges has been much disputed, but at the same time it has had many able defenders, and may be followed with perfect reliance and safety. If it errs, it errs on the right side—that of understating the real strength; it is

$$w = \frac{a\,d\,c}{l}$$

where w = the centre breaking weight in tons irrespective of the weight of the girder
a = sectional area of bottom in inches
d = depth of beam in inches
c = a constant derived from experiment for the particular form of girder, and
l = length of girder between the supports in inches.

The formula always assumes a well made and well proportioned girder, having the relative areas of 12 to 11 in the top and bottom and the chain riveting.

The constant c for the tubular girders we have described was ascertained to be 80. Let us now find by this formula the strength of one of the spans of the Trent bridge

TABLE showing the Proportions of Tubular Girder Bridges, from 30 to 150 Feet Span.

Span	Centre Breaking Weight of Bridge.	Sec. Area of Bottom of one Girder.	Sec. Area of Top of one Girder.	Depth at the Girder in the Middle.
Feet. In.	Tons.	Inches.	Inches.	Feet. In.
30 0	180	14·63	17·06	2 4
35 0	210	17·06	19·91	2 8
40 0	240	19·50	22·75	3 1
45 0	270	21·94	25·59	3 6
50 0	300	24·38	28·44	3 10
55 0	330	26·81	31·28	4 3
60 0	360	29·25	34·13	4 7
65 0	390	31·69	36·97	5 0
70 0	420	34·13	39·81	5 5
75 0	450	36·56	42·67	5 9
80 0	480	39·00	45·50	6 2
85 0	510	41·44	48·34	6 7
90 0	540	43·88	51·19	6 11
95 0	570	46·31	54·03	7 4
100 0	600	48·75	56·88	7 8
110 0	660	53·63	62·56	8 6
120 0	720	58·50	68·25	9 3
130 0	780	63·38	73·94	10 0
140 0	840	68·25	79·63	10 9
150 0	900	73·13	85·31	11 6

TABLE showing the Proportions of Tubular Girder Bridges, from 160 to 300 Feet Span.

Span.	Centre Breaking Weight of Bridge.	Sec. Area of Bottom of one Girder.	Sec. Area of Top of one Girder.	Depth at the Girder in the Middle.
Feet. In.	Tons.	Inches.	Inches.	Feet. In.
160 0	960	90·00	105·00	10 8
170 0	1020	95·63	111·56	11 4
180 0	1080	101·25	118·13	12 0
190 0	1140	106·88	124·69	12 8
200 0	1200	112·50	131·25	13 4
210 0	1260	118·13	137·81	14 0
220 0	1320	123·75	144·38	14 8
230 0	1380	129·38	150·94	15 4
240 0	1440	135·00	157·50	16 0
250 0	1500	140·63	164·06	16 8
260 0	1560	146·25	170·63	17 4
270 0	1620	151·88	177·19	18 0
280 0	1680	157·50	183·75	18 8
290 0	1740	163·13	190·31	19 4
300 0	1800	168·75	196.88	20 0

which we have described. By reference to *fig.* 504, it will be observed that here $a=58\cdot5$, $d=144$, and $l=1848$.

$$w=\frac{a\,d\,c}{l}=\frac{58\times144\times80}{1848}=364\cdot6 \text{ tons}$$

as the weight which a tubular girder 154 feet between the supports will carry suspended from one point in the centre before fracture. Now the actual weight of this girder itself is under 70 tons, and it may safely be asserted that no other form of construction would give so favorable a result. The centre breaking weight of one girder being 364½ tons, it would carry 729 tons equally distributed along its entire length, and there being two main girders to the bridge, the ultimate strength of the structure is in round numbers, 1,500 tons. It would be possible, by both lines of railway being covered with heavy goods train, to have a load on the bridge of about 250 tons at one and the same time, and we thus see there is a margin of strength of six times the greatest possible load. Engineers differ in opinion as to the excess of strength which it is desirable that railway structures should possess; some are satisfied with even as low an ultimate breaking strength as three times the load; but with a comparatively untried material, and one moreover liable to deterioration from atmospheric influences, the larger excess is the better.

On the discovery of Mr. Fairbairn's cellular arrangement for the top compartment of the Conway and Britannia Bridges, several able mathematicians advocated the introduction of iron cylindrical instead of rectangular cells, as being a better distribution of the material to resist the compressive strain. Mr. Fairbairn's original views were in the same direction, but were abandoned on account of the complexity of construction and the difficulties of manufacture, and it is curious to notice now that subsequent scientific investigations have confirmed the practical engineer's views, and shown that the rectangular cells are superior in strength. Mr. Tate especially thus ingeniously argues:—"The cells in a transverse strain undergo a different kind of strain to what they are subjected to in a simple crushing force equally distributed over the section of the tube. In this case all the parts of the section are equally compressed, and it is reasonable to conclude that the best form of cell will be that in which the material is equally distant from the axis of pressure; but the case of transverse strain is very different, *the upper edge undergoes the greatest strain*, and of the other parts that which is nearest the natural axis of the beam undergoes the least; in this case therefore the material in the square cells is symmetrically distributed with respect to the axis of pressure, the neutral axis of the beam."

The Durability of Tubular Girders—On this head there is as yet but a very limited experience as a basis for positive assertion. There can be no doubt that if neglected the effects of oxidation upon the wrought-iron plates and rivets would speedily be productive of very disastrous results. On the other hand, there are many existing examples of wrought-iron structures, such as iron ships and other vessels, suspension bridges, &c., which with proper care and attention have withstood the wear and tear of constant exposure and use without any serious impairment of their powers of resistance, for periods of upward of thirty years. It will be noticed too that tubular bridges have been designed with an especial view to the easiest access to every part for the purposes of painting and repairs, and it is not therefore improbable that with attention these structures will prove to be more durable than either cast-iron, timber, or other structures similarly situated.

Their Cost.—In estimating the cost of a tubular girder bridge, one of their most important recommendations must not be overlooked, viz., the saving which they afford in the construction of the masonry, abutments, and piers. For example, in the formation of a bridge of 150 feet span, if cast iron or stone be the material employed, vast sums of money would have to be expended in the formation of ponderous and solid abutments to receive the thrust of the arch and its load, whereas with the girder bridge two simple well-constructed walls giving a bearing of five or six feet to the ends of the girders is all that is necessary, the girders themselves receiving and maintaining the strain due to the load. The mere iron superstructure may thus in some cases appear costly, but when the whole of the adjuncts of a bridge are taken into consideration there is perhaps no other form of *pontitecture* which can compete with the wrought-iron girder when the clear space exceeds 70 feet. In estimating the cost of the iron superstructure it may be assumed, when the value of manufactured iron is at an average rate, at 20*l.* per ton weight fixed and erected.

General Advantages.—The more prominent advantages of these ingenious structures, viz. lightness, strength, security, and economy, have been referred to in the foregoing remarks. In addition they are a ready resource to the engineer in localities where he is limited for space. Thus, in crossing at a low level a road, river, or canal, a height of 15 inches from the bottom of the bridge to the level of the roadway will suffice for a width of bridge which will admit of a double line of railway or ordinary turnpike road.

Again, the structures are inexpensively fixed. The Trent girders, for example, were constructed on the railway embankment close to the west abutment of the bridge, and drawn across to their permanent places without the expense of scaffolding, &c. in the river. The main girders themselves, in addition to forming the main strength of the bridge, form parapets and protection to the traffic.

In conclusion, it may be stated that, although devoid of the massive but imposing elegance of the stone arch or the fairy lightness of the suspension roadway, the beauty of a tubular girder bridge consists in its usefulness and its evident fitness for the work it has to perform.

THE BRIDGE OVER THE RHINE BY COLOGNE.—"During the course of autumn, 1849, Mr. Fairbairn of Manchester, was induced by representations made to him through a high official functionary, to propose to the Prussian Government a plan for an iron bridge across the Rhine at Cologne on the tubular principle. This plan met with the entire approbation of the scientific world at Berlin, was sanctioned by the King, and was all but adopted by the Prussian Cabinet. It happened, however, that simultaneously with the proposal of Mr. Fairbairn. one Oberbaurath Lentze had become convinced that a suspension bridge was the true means of communication across the Rhine. He had arrived at this conclusion after years of patient investigation, and so far worthy of all praise, though it somewhat unfortunately chanced that his discovery was some thirty years too late, so that his labors, which would have been at the height of science in 1820, have only served to illustrate a job in 1850. Here, in England, we have some little notion of the nature of jobs, but we question whether any more colossal in this kind has ever been perpetrated in our palmiest days of corruption than the attempt of our worthy friend Herr Van der Heydt, in whose paper, if we are not mistaken, the celebrated figment of the payment of 6,000*l.* to the editors of the 'Times' by the Danish Government first appeared, to bolster up the scheme of M. Lentze, and to throw cold water upon that of Mr. Fairbairn. What mattered it that Baron Humboldt, the Nestor of physical science, sided with Mr. Fairbairn, or that the King of Prussia, in one of his happy moments, had graciously extended his royal protection to the English engineer? Was not M. Van der Heydt, and the whole army of the Prussian bureaucracy, whose name is Legion, arrayed on the other side? Still the English scheme must be burked officially; it was to be smothered in due form with the cushion of bureaucracy; so a commission was appointed to inquire into the English tubular bridges; and of whom do our readers suppose that it consisted? Why of Herr Oberbaurath Lentz himself and another person, who, after due deliberation, set off for England on their scientific mission. Why need we detail at length the wanderings of these duumviri of bureaucracy? how they landed in England—how they were received with marked courtesy by Mr. Fairbairn—how they saw the Conway Bridge, the Britannia Bridge, and other structures of minor dimensions in Lancashire? Suffice it to say that they were quite blind to the merits of tubular bridges, and made their report dead against tubular bridges and strongly in favor of suspension bridges—a report which was adopted by the government, that is to say, by Herr Van der Heydt, who forthwith issued his famous notice, calling upon the engineers of the whole world to compete for the honor of contributing to the glorification of Herr Oberbaurath Lentze, whose plans have been long since in the bureau of M. Van der Heydt, and in all probability will be ultimately carried out."—*Times.*

W. Fairbairn, Esq., to Baron Humboldt.

"My dear Baron Humboldt,—I gather, from an article which has recently appeared in the 'Times' newspaper, and from a communication which his Excellency M. Van der Heydt has honored me with, that a most unfortunate decision has been come to by the authorities at Berlin, with reference to the important structure by which it is intended to connect the opposite banks of the Rhine at Cologne. It having been my good fortune to have been consulted, many months ago, on the subject of this important bridge, and to have visited Berlin for the purpose of submitting my proposals, I hold it due to the warm recommendation which emanated from our excellent friend in London, the Chevalier Bunsen—to the lively interest you manifested in favor of the object of my journey, and also to the gracious approval expressed by His Majesty the King of Prussia in person—to make known as widely as possible the insuperable objections which, in my opinion, attach to the limited programme which has recently been issued from the bureau of the Minister of Public Works.

"So far as words can be allowed to convey an intimation of a genuine conviction, M. Van der Heydt acknowledged at the palace, on the 1st of November last, that no structure should ever be allowed to cross the Rhine which was not calculated to meet, with perfect security, the utmost requirements of the most extended traffic, and the possible contingencies of great military operations. Your own enlarged conceptions at once prompted you to acknowledge that the design (which at that time had received the sanction of the authorities) was totally unfit for these purposes, and to admit that a suspension bridge, owing its strength to a flexible catenary, was inadequate to the transport of heavy weights. But when I submitted the results which had been accomplished in this country by the judicious application of a material until recently untried in such structures—when I announced the successful realization of one of the boldest conceptions of modern times—when I stated that tidal streams, such as the river Conway and the Menai Straits, had been crossed by solid and unyielding bridges of enormous span, which were capable nevertheless of sustaining ten times the greatest possible strain that the heaviest railway traffic could, in practice, subject them to—when I had shown that this new principle of construction was peculiarly adapted

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to surmount the numerous difficulties which the passage of the Rhine offers, by requiring very few and comparatively small piers in the stream, and thus allowing of the passage of large timber rafts in the summer, and offering the least possible resistance in times of floods and breaking up of ice in the winter; and, above all, when I had proved that a structure so much superior could be erected and fixed at an outlay considerably below that which had been demanded for a very imperfect one—I confess I was not prepared to find the Minister of an enlightened and powerful people asking for the assistance of the world at large to perpetuate a scheme unworthy of Prussia, unworthy of the practical scientific knowledge of the age, and in opposition to the deliberate and carefully-weighed opinion of Science's greatest ornament.

"Pardon me for the warmth with which I address to you this remonstrance; but I feel that your unwearied exertions, and the friendship which you unreservedly testified to me, call upon me to urge, as forcibly as I can, the retracing of the unfortunate steps already taken. We live in times of progress. A scientific discovery, or a practical improvement of any kind, cannot be confined to a particular locality or to one country, it becomes at once the property of all. The community of Knowledge—the most powerful destroyer of national prejudices and antipathies, as it is the surest foundation for general and permanent peace and good will—must ride over and bear down individual ignorance and petty bureaucratic objections. Punctuality and rapidity in our inter-communications have become almost essentials of our existence; and in this manner all Europe may be said to be interested in the completion of that railway system which will traverse the Prussian dominions from one extremity to the other.

"And now let me point out the lamentable imperfections which characterise the Minister's programme, and the limitations and requirements which will effectually trammel the efforts of men of genius, and deter those of experience and reputation from entering at all upon the competition.

"It is an express condition of the scheme that the railway communication is not to be continuous, and the public will therefore continue to suffer the annoyance and inconvenience of considerable delays; for it may be safely said that the proposal of disintegrating a train at one terminus and drawing it across to the other by men or horses, bit by bit, and hour by hour, will offer equal, if not greater, obstacles to a rapid journey than the existing system does. How much better would it be that the bridge should embody within itself such elements of strength and durability as would afford at all times and in all seasons a safe transit to those means of locomotion which constitute the wonder and glory of the age? Instead of such a permanent and substantial structure, will the Prussian Government sanction the erection of one, the feeble and rickety constitution of which would shudder at the very sight of a locomotive? Surely not! Public opinion must step in and forbid it. What is wanted is a bridge to connect the existing railways, not one that will permanently separate them.

"But again; it is stated that the difference between the levels of the existing railways and that required for the roadway of the intended bridge is too great to be overcome by the locomotive within a short distance of length. The objection is purely imaginary; for I can state from personal examination, that the necessary gradient would not be so heavy as several which are worked with great ease in this country Besides, on the left bank of the Rhine the terminus of the Aix-la-Chapelle line is at the right level; and that on the side of Deutz may without difficulty be reached by any easy gradient of less than 1 in 100.

"Without meaning the slightest disrespect to the author of the design for the chain bridge, I must repeat my firm and deliberate conviction, that it would prove an incomplete and unsatisfactory structure. A permanent, inflexible, durable, and handsome bridge, of enormous strength (the breaking weight of the bridge I proposed, with the span of 310 feet. was equal to 6,000 tons or 120,000 cwt., equally distributed over each span, giving as the ultimate strength of the bridge, with four spans, 24,000 tons, or 480,000 cwts.), adapted, by arrangements which I have now in progress of execution for similar purposes in this country, to give every possible facility to the navigation of the river—calculated to carry across the heaviest railway train at any speed, and which you might cover with the most powerful ordnance from end to end, may be erected at Cologne within the sum which has been demanded for the chain bridge. These statements are not the imaginings of a sanguine mind; but their accuracy may be corroborated by numerous examples of a similar character which have been erected in this country.

"If, therefore, the determination of the Minister of Public Works to erect a chain bridge cannot be shaken, I confidently anticipate that such an event will not be allowed to pass by without a strong protest on the part of those who are in advance of the knowledge and judgment displayed by the authors of the invitation which has been issued to the engineering world.

"My letter has attained a much greater length than I at first anticipated. My anxiety to forward your own forcibly expressed views on the subject of a fixed bridge must be my apology for it.

"With an expression of my profound esteem, and with best wishes for your continued good health,

Believe me to remain, my dear Baron Humboldt, your very faithful and very obedient servant,

"William Fairbairn."

"*Manchester, April 15.*"

Fairbairn's Wrought-Iron Girder Bridge. *Report on the Strength, Elasticity, and other Properties of Wrought-Iron Girder Bridges as applicable to Railways and other Structures. By* W. Fairbairn, Esq., C. E. (From the Appendix to Report of the Commissioners appointed to inquire into the application of Iron to Railway Structures.)—"The idea of crossing the River Conway and the Menai Straits on the line of the Chester and Holyhead Railway (two of the most formidable barriers ever presented to the engineer), properly belongs to Mr. R. Stephenson.

"To carry this into practice, required the united skill of the mechanical as well as the civil engineer; and it is highly gratifying to find that the successful completion of the first of the Conway tubes has not only attained that object, but it has established a new era in the history of bridges, by the development of the properties of a hitherto untried material, and enables the engineer of the present day to conquer obstacles which, at no very distant date, were considered insurmountable.

"An undertaking of such importance to the scientific world, to the public, and to those more immediately interested, involving heavy responsibilities on the engineer; before anything definite could be accomplished, it became absolutely necessary to institute a series of experiments to determine the practicability of such a structure, including other inquiries into the proportions and other properties of the tube. At the request of Mr. Stephenson, I had the honor of being selected to conduct this inquiry.

"Experiments on circular, elliptical, and rectangular tubes were accordingly undertaken; but it soon became evident from the results obtained that those of a rectangular form were best calculated for the purpose. It was not, however, until I had adopted the tube with the corrugated top that the real value of the tubular form became apparent, and, in fact, absolutely requisite in that part to offer sufficient resistance to the crushing force.

"I will not trouble the Commissioners with the details of the experiments, but simply state that it evidently became necessary to adopt some other shape than those of the circular and elliptical kind, and so to proportion the top and bottom sides of the tube as to effect a balance of the resisting forces of extension and compression, and thus to ensure the maximum force of resistance in every part. These proportions were clearly indicated by the rectangular form; and the formation of cells on the top side give more effective powers of resistance to the crushing force than had been heretofore accomplished by the single plate.

"This discovery of the cellular top, and the greatly increased value which a tube thus constructed gave to the experiments, at once suggested a modified form of tubular girder adapted to shorter spans. This description of bridge is now becoming general; and from its superior powers of resistance, greater security, and its adaptation to almost every description of span, we may reasonably infer that wrought iron is cheaper and safer, if not equally durable with any other description of materials. It may, and I have no doubt it will be urged, that wrought-iron is much more subject to oxidation and decay than cast-iron or stone; a circumstance which cannot be disputed; but that can only arise from gross negligence on the part of those having charge of the structure, as two coats of good oil paint every three years will effectually protect it. and render it durable for almost any length of time. Besides, the girders, as now constructed, are accessible in every part, and, by careful attention, I can see no reason why they should not last 500 instead of 50 or 100 years. Another objection brought against this description of bridge is, the risk of the rivets becoming loose; and from the number of joints, the whole is considered by some as dangerous and insecure. Now, as regards this objection, no real weight can be attached to it; as the parties raising it cannot be acquainted with the nature and solidity of the work. It is next to impossible for a single rivet to get loose (unless the work is improperly executed); and in the whole of my experience, I am not acquainted with any description of jointing so certainly secure, and so well adapted to resist any description of strain, as that of riveted plates. I speak practically and unhesitatingly on this subject; and I have only to instance steam boilers, iron ships, and other vessels subjected to severe strain, as examples of the strength and tenacity of riveted plates; in fact, rivets seldom or never get loose, but retain their position under every species of strain, and become, as it were, integral parts of the structure in common with the plates themselves.

"In submitting these remarks to the consideration of the Commissioners, and in order to bear them out, it may not be uninteresting briefly to notice a few of the results of the experiments illustrative of this subject, and to show, with a greater degree of exactitude, the nature and value of this description of structure. For these objects, I beg to insert a few of the earlier experiments on different descriptions of tubes, as recorded in a report addressed to Mr. Stephenson and the directors of the Chester and Holyhead Railway, the particulars of which have already been before the public."

(Here follow the details of the experiments referred to.)

The experiments, of which the above is a brief notice, have led to other improvements of great utility in practical science, and probably of equal value with those for which they were originally undertaken.

"I have already stated that the difficulty which the weakness of the material to resist a crushing force occasioned, was overcome by the adoption of the cellular form of top; but another, and, to my mind, very serious difficulty presented itself, in the reduction in the strength of the plates at the joints by the ordinary method of riveting, in the bottom and those parts where the tensile strain came into operation. This led to a new system of riveting, which, without weakening the body of the plate to so great an extent as formerly, gives a joint of almost equal strength with the plate itself, and thus adds in a most material manner to the security of the structure.

"Consequent upon the experiments and the results obtained therefrom, numerous advantages presented themselves in the construction of wrought-iron girders. The strength, ductility, and comparative lightness of the material are the important elements of these girders; and their elasticity, retention of form, and other properties, render them infinitely more secure than those composed of cast-iron, which, from the brittle nature of the material and imperfections in the castings, are liable to break without notice, and to which the wrought-iron girder is not subject. This is, however, probably of less importance, as the wrought-iron girder will be found not only cheaper, but (when well constructed, and upon the right principle) upwards of three times the strength of cast-iron. I have elsewhere stated to the Commissioners that the experiments attracted the notice generally of railway engineers, and, amongst others, that of Mr. Vignoles, who immediately gave an order for two wrought-iron girder bridges for the Blackburn and Bolton Railway Company:—one to cross the Liverpool and Leeds Canal, and the other over the turnpike road, both in the vicinity of Blackburn. These bridges were constructed simultaneously with another of similar form (with a cast-iron top) executed by Mr. Dockray, under the direction of Mr. Robert Stephenson, for carrying the turnpike road over the London and North-Western Railway at Camden Town. Those for the Blackburn and Bolton Railway were, however, the first adapted for railway traffic; and although they are probably not so well proportioned as others since constructed, they nevertheless exhibit extraordinary powers of resistance; and conceiving that a description of these bridges, with the tests to which they were subjected, might be useful, I have great pleasure in submitting the same, with the necessary drawings, to the consideration of the Commissioners.

Explanation of the Engravings, descriptive of the Hollow Girder Bridge over the Turnpike Road near Blackburn.

"*Fig.* 521 is an elevation or side view of the girder, each 66 ft. long, and bedded on cast-iron base plates.

"*Fig.* 522 is a transverse section of the bridge, showing the sides of the cross-beams, and the cross sections of the outside and middle girders.

"*Fig.* 523 is an enlarged transverse section of the outside girder, showing the attachment of the cross-beams, which are riveted to the bottom of the girder, exclusive of two bolts A A, which extend through the bottom plates and angle iron of the girder, and the top and bottom plates of the cross-beam.

"*Fig.* 524 is an enlarged view of a part of the side of the large girder, exhibiting a transverse section of the cross beam, at B, which is made of wrought-iron, with the top and bottom plates so proportioned as to equalise its powers of resistance to the force of compression on the top, and that of tension on the bottom. It also exhibits the mode of riveting up the joints of the side plates with the covering strip C C C, and the additional strength as obtained by the attachment of T iron in the interior of the tube.

"*Fig.* 525 is a plan of the bridge, showing on one side the platform and the rails, and on the other the cross-beams, which in this bridge are placed 6 ft. asunder; but in those more recently constructed, I have placed them at distances of only 4 ft., and consider this arrangement preferable.

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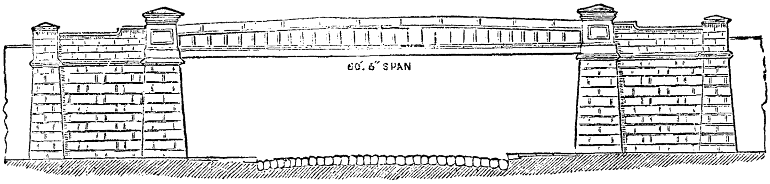

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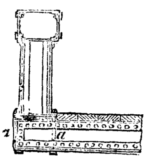

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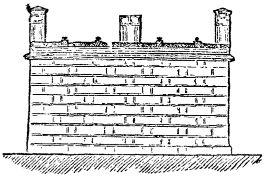

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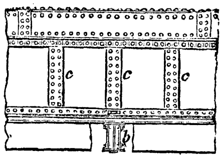

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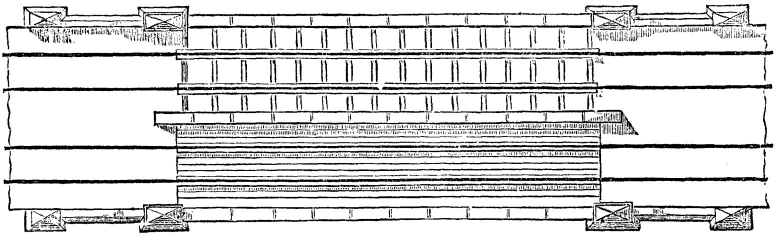

"From the above description it will be seen that the whole is a strong and perfectly rigid structure. With three longitudinal girders, a bridge of this description will support a load equally distributed of 760 tons; and in order to render it safe, under every species of strain, the middle girder is made nearly double the strength of those on the outside. This is essential, as two trains may be passing the bridge at the same moment; in which case the middle girder would be subjected to a pressure equal to double the load on the outside girders.

"In the construction of bridges of larger span, I generally prefer only two large longitudinal girders with strong cross-beams every three feet, of sufficient length to admit two lines of rails, and sufficient room for two trains to pass at the same time. This mode of construction is preferable to the three girders, as it effects greater simplicity in the structure, and, from every appearance, renders the bridge equally effective and secure.

"Having thus described the advantages peculiar to this description of bridge, I will now direct the attention of the Commissioners to the tests to which the Blackburn Bridge was subjected, previous to its opening for public traffic. The experiments were made in the presence of Captain Coddington, the Government Inspector of Railways, and Mr. Flanagan, engineer of the line, as follows:—

"Three locomotive engines, weighing 60 tons, were coupled together, and passed over the bridge at velocities varying from 5 to 15, and 25 miles an hour. This load (60 tons) produced a deflection of ·025 of a foot, or about $\frac{3}{10}$ths of an inch, and that without any perceptible increase in the deflection arising from the different rates of speed. In fact the deflection was found to be the same at all velocities.

"After these tests were made, two wedges or inclined plates were fitted to the rails, *fig.* 526, at the middle of the bridge, and the engines run over them at the rate of 1 to

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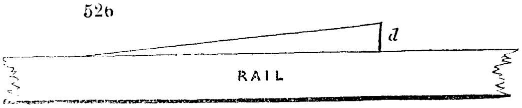

10 miles an hour. The shock of the engines, as they respectively fell upon the girders, from a height of one inch, the thickness of the wedge at D, gave an increased deflection from ·025 to ·035 of a foot, and another set of wedges, 1½ feet in height, gave a further increase of deflection (at the same velocity) of ·035 to ·045 of a foot.

"From the above experiments it appears evident that wrought-iron girders are well calculated to resist not only a heavy dead weight, but the force of impact administered with an unsparing hand; for, in fact, the girders were not injured by the blows inflicted by engines falling a height of $1\frac{1}{2}$ inches upon them, but restored themselves to their original position from which they were deflected by the shock.

"On the whole we may, therefore, reasonably conclude that the present structure is not only the strongest, but the best calculated to resist strain when applied to large spans, and particularly in situations where bridges, with a perfectly horizontal soffit, are alone admissible.

(Signed) "William Fairbairn."

'Manchester, April 26th, 1848."

FAN (*Eventail*, Fr.; *Fächer*, Germ.) is usually a semi-circular piece of silk or paper, pasted double, enclosing slender slips of wood, ivory, tortoise-shell, whale-bone, &c., arranged like the tail of a peacock, in a radiating form, and susceptible of being folded together, and expanded at pleasure. This well-known hand ornament is used by ladies to cool their faces by agitating the air. Fans made of feathers, like the wing of a bird, have been employed from time immemorial by the natives of tropical countries.

Fan is also the name of the apparatus for winnowing corn. For an account of the powerful blowing and ventilating fan machine, see Foundry and Ventilator.

FARINA (*Farine*, Fr.; *Mehl*, Germ.) is the flour of any species of corn, or starchy root, such as potato, arrow root, &c. See Bread and Starch.

FATS (*Graisses*, Fr.; *Fette*, Germ.) occur in a great number of the animal tissues, being abundant under the skin in what is called the cellular membrane, round the kidneys, in the folds of the omentum, at the base of the heart, in the mediastinum, the mesenteric webb, as well as upon the surface of the intestines, and among many of the muscles. They vary in consistence, color, and smell, according to the animals from which they are obtained; thus, they are generally fluid in the cetaceous tribes, soft and rank-flavored in the carnivorous, solid and nearly scentless in the ruminants, usually white and copious in well-fed young animals; yellowish and more scanty in the old. Their consistence varies also according to the organ of their production; being firmer under the skin, and in the neighborhood of the kidneys, than among the moveable viscera. Fat forms about one twentieth of the weight of a healthy animal. But as taken out by the butcher it is not pure, for being of a vesicular structure, it is always enclosed in membranes, mixed with blood, blood-vessels, lymphatics, &c. These foreign matters must first be separated in some measure mechanically, after the fat is minced small, and then more completely by melting it along with hot water, passing it through a sieve, and letting the whole cool very slowly. By this means a cake of cleansed fat will be obtained. Many plans of purifying fats have been proposed; one of the best is to mix two per cent. of strong sulphuric acid with a quantity of water, in which the tallow is heated for some time with much stirring; to allow the materials to cool, to take off the supernatant fat, and re-melt it with abundance of hot water. More tallow will thus be obtained, and that considerably whiter and harder than is usually procured by the melters.

I have found that chlorine and chloride of lime do not improve, but rather deteriorate, the appearance of oils and other fatty bodies. According to Appert, minced suet subjected to the action of high-pressure steam in a digester, at 250° or 260° F., becomes so hard as to be sonorous when struck, whiter, and capable, when made into candles, of giving a superior light A convenient mode of *rendering* minced tallow, or melting it, is to put it in a tub, and drive steam through it from numerous orifices in ramifying pipes placed near the bottom. Mr. Watt assures me that his plan of purifying fats, patented in March, 1836, has been quite successful. He employs dilute sulphuric acid, to which he adds a little nitric acid, with a very small quantity of bichromate of potash, "to supply oxygen;" and some oxalic acid. These are mixed with the fat in the steaming tub. When the lumps of it are nearly dissolved, he takes for every ton of fat, one pound of strong nitric acid, diluted with one quart of water; to which he adds two ounces of alcohol, naphtha, sulphuric ether, or spirits of turpentine; and after introducing this mixture, he continues the boiling for half an hour. The fat is finally washed. As I do not comprehend the *modus operandi* of these ingredients, I shall abstain from any comment upon the recipe.

Others have proposed to use vegetable or animal charcoal first, especially for rancid oils, then to heat them with a solution of sulphate of copper and common salt, which is supposed to precipitate the fetid albuminous matter. Milk of lime has been also prescribed: but it is, I believe, always detrimental.

Davidson treats whale oil with infusion of tan, in order to separate the gelatine and albumine in flocks; next with water and chloride of lime, to destroy the smell; and lastly, with dilute sulphuric acid, to precipitate all the lime in the state of a sulphate. This is certainly one of the cheapest and most effective methods of purifying that substance.

Braconnot and Raspail have shown that solid animal fats are composed of very small, microscopic, partly polygonal, partly reniform particles, which are connected together by very thin membranes. These may be ruptured by mechanical means, then separated by triturating the fresh fats with cold water, and passing the unctuous matter through a sieve. The particles float in the water, but eventually collect in a white granular crystalline appearance, like starch. Each of them consists of a vesicular integument, of the nature of stearine, and an interior fluid like elaine, which afterwards exudes. The granules float in the water, but subside in spirits of wine. When digested in strong alcohol, the liquid part dissolves, but the solid remains. These particles differ in shape and size, as obtained from different animals; those of the calf, ox, sheep, are polygonal, from $\frac{1}{50}$ to $\frac{1}{350}$ of an inch in diameter; those of the sow are kidney-shaped, and from $\frac{1}{50}$ to $\frac{1}{100}$; those of man are polygonal, and from $\frac{1}{50}$ to $\frac{1}{600}$; those of insects are spherical, and at most $\frac{1}{500}$ of an inch.

Fats all melt at a temperature much under 212° F. When strongly heated with contact of air, they diffuse white pungent fumes, then blacken, and take fire. When subjected to distillation, they afford a changed fluid oil, carbureted hydrogen, and the other products of oily bodies. Exposed for a certain time to the atmosphere, they become rancid, and generate the same fat acids as they do by saponification. In their fresh state they are all composed principally of stearine, margarine, and oleine, with a little coloring and odorous matter; and in some species, hircine, from the goat; phocenine, from the dolphin; and butyrine, from butter. By subjecting them to a great degree of cold, and compressing them between folds of blotting paper, a residuum is obtained, consisting chiefly of stearine and margarine; the latter of which may be dissolved out by oil of turpentine.

Beef and Mutton Suet.—When fresh, this is an insipid, nearly inodorous fat, of a firm consistence, almost insoluble in alcohol, entirely so if taken from the kidneys and mesenteric web of the ox, the sheep, the goat, and the stag. It varies in its whiteness, consistence, and combustibility, with the species and health of the animals. That of the sheep is very white and very solid. They may all be purified in the manner above described. Strong sulphuric acid developes readily the acid fats by stirring it through melted suet. Alkalis, by saponification, give rise at once to the three acids,—the stearic, margaric, and oleic. Beef suet consists of stearine, margarine, and oleine; mutton and goat suet contain a little hircine. The specific gravity of the tallow of which common candles are made is, by my experiments, 0·936. The melting point of suet is from 98° to 104° F. The proportion of solid and fluid fat in it is somewhat variable, but the former is in much larger proportion. Mutton suet is soluble in 44 parts of boiling alcohol, of 0·820; beef suet in 44 parts. Marrow fat consists of 76 of stearine, and 24 of oleine; it melts at 115° F.

Hog's-lard is soft, fusible at 81° F., convertible, by an alkaline solution, into a stearate, margarate, oleate, and glycerine. Its sp. grav. is 0·938, at 50° F. It consists of 62 of oleine, and 38 of stearine, in 100 parts.

Goose-fat consists of 68 oleine and 32 stearine.

Butter, in summer, consists of 60 of oleine and 40 of stearine; in winter, of 35 of oleine, and 65 of stearine; the former substance being yellow, and the latter white It differs, however, as produced from the milk of different cows, and also according to their pasture.

The ultimate constituents of stearine, according to Chevreul, are 79 carbon, 11·7 hydrogen, and 9·3 oxygen, in 100 parts.

1,294,009 cwts. of the tallow imported in 1837 were retained for internal consumption. See MARGARINE, OLEINE, SOAP, STEARINE.

The following statement is given on the authority of Braconnot:—

	Oleine.	Stearine.
Fresh Butter in summer - - - -	60	40
——— in winter - - - -	37	63
Hog's Lard - - - - - -	62	38
Ox Marrow - - - - - -	24	76
Goose Fat - - - - - -	68	32
Duck Fat - - - - - -	72	28
Ox Tallow - - - - - -	25	75
Mutton Suet - - - - - -	26	74

M. Dumas says that butter contains no stearine. The purification and decoloration of fats have been the object of many patents. Under CANDLE, Hempel's process for refining palm-oil and extracting its margarine is described.

About 30 years ago, palm-oil was deprived of color to a certain degree by mixing with the melted oil, previously freed from its impurities by filtration, some dilute nitric

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acid, wooden vessels being used, and the oil being in a melted state. This process was both expensive and imperfect. More lately whitening has been prescribed by means of chromic acid, which, in the act of decomposition into chromic oxide, gives out oxygen, and thereby destroys vegetable colors. One pound of bichromate of potash in solution is to be mixed with two pounds of strong sulphuric acid, diluted beforehand with about two gallons of water; and this mixture is to be incorporated by diligent stirring with 2 cwt. of the filtered palm-oil, at a temperature of about 100 F., contained in a wooden vessel. The palm-oil is afterward to be washed in warm lime-water, to which some solution of chloride of lime may be advantageously added. By this process, well managed, a fat may be obtained from palm-oil fit for making white soap. Tallow may be also blanched to a considerable degree by a like operation.

Instead of sulphuric acid, the muriatic may be used to convert the chromic acid into chromic oxide in the above process, and thereby to liberate the blanching oxygen. The resulting solution of green muriate of chrome being freed from some adhering oil, is to be mixed with so much milk of lime as just to neutralize the excess of acid that may be present. The clear green muriate is then to be decomposed in a separate vessel, by the addition of well-slaked and sifted lime, in some excess. The green mixture of lime and chrome-oxide is now to be dried, and gently ignited, whereby it is converted into yellow chromate of lime, with some unsaturated lime. This compound being decomposed by dilute sulphuric acid, affords chromic acid, to be applied again in the decoloring of palm-oil, on the principles above explained.

Mr. Prynne obtained a patent in March, 1840, for purifying tallow for the candle-maker, by heating it along with a solution of carbonate of potash or soda for 8 hours, letting the whole cool, removing the tallow to another vessel, heating it by means of steam up to 206° F., along with dry carbonate of potash (pearlash): letting this mixture cool very slowly; and finally removing the tallow to a vessel enclosed in steam, so as to expel any subsidiary moisture.—*Newton's Journal*, xxi. 258.

A patent for a like purpose was obtained in June, 1842, by Mr. H. H. Watson. He avails himself of the blanching power of oxygen, as evolved from manganate of potash (chameleon mineral), in the act of its decomposition by acids, while in contact with the melted fat. He prescribes a leaden vessel (a well-joined wooden tub will also serve) for operating upon the melted tallow, with one twentieth of its weight of the manganate, dissolved in water, and acidulated to the taste. The whole are to be well mixed, and gradually heated from 150° up to 212° F., and maintained at that temperature for an hour. On account of the tendency of the dissolved manganate to spontaneous decomposition, it should be added to the dilute acid, mixed with the fat previously melted at the lowest temperature consistent with its fluidity.

Palm-oil may be well blanched in the course of 12 hours by heat alone; if it be exposed in a layer of one or two inches to the air and sunshine, upon the surface of water kept up at nearly the boiling point by a coil of steam-pipes laid in the bottom of a square cistern of lead or wood, well jointed.

Mr. Wilson, of Vauxhall, has applied centrifugal action to the separation of the more liquid from the more solid parts of fatty matters, using in preference the *hydro-extractors* used by Seyrig and Co., for drying textile fabrics. Mr. Wilson employs a stout cotton twill in addition to the wire grating; and in order to avoid the necessity of digging the concrete parts, and to prevent them from clogging the interstices for the discharge of the oily matter, he places the whole in a bag 8 inches in diameter, and of such length that when laid on the rotating machine against the grating the two ends will meet. The speed of the machine must be kept below that at which stearic acid or stearine would pass; which is known by the limpidity of the expressed fluid. To take advantage of the liquefying influence of heat, he keeps the temperature of his room about 2° F. above that of the substances under treatment.

The improved fat and candle factory, called *Price's*, of which Mr. Wilson, of Belmont, Vauxhall, seems to be the main conductor and schemer, is mounted upon a colossal scale. It has five separate works near London, great plantations of cocoa-nut trees in Ceylon, with a capital of about half a million sterling, an annual division of profits to the amount of 50,000*l.*, and it employs about 800 work-people, whose physical and moral well-being is well looked after by the benevolent manager of the whole concern. See CANDLES.

Tallow imported for home consumption in 1850, 1,219,101 cwt.; in 1851, 1,085,660 cwt. Gross amount of duty received, 78,270*l.* and 68,035*l.* respectively; the duty being 1*d.* per cwt. from British possessions, and 1*s.* 6*d.* per cwt. from foreign countries.

FAT BLEACHING. By transmitting streams of atmospheric air through heated palm-oil and other colored and odorous fatty matters, they are deprived so far of their color and smell as to be capable of forming white soaps. Mr A Dunn obtained a patent for this object in 1843.

FAULTS (*Failles*, Fr.), in mining, are disturbances of the strata which interrupt the miner's operations, and put him at *fault*, to discover where the vein of ore or bed of coal has been thrown by the convulsions of nature. Many examples of faults are exhibited under PITCOAL.

FEATHERS (*Plumes*, Fr.; *Federn*, Germ.) constitute the subject of the manufacture of the *Plumassier*, a name given by the French (and also the English) to the artisan who prepares the feathers of certain birds forornaments to the toilet of ladies and for military men, and to him also who combines the feathers in various forms. We shall content ourselves with describing the method of preparing ostrich feathers, as most others are prepared in the same way.

Several qualities are distinguished in the feathers of the ostrich; those of the male, in particular, are whiter and more beautiful. Those upon the back and above the wings are preferred; next, those of the wings, and lastly, of the tail. The down is merely the feathers of the other parts of the body, which vary in length from 4 to 14 inches. This down is black in the males, and gray in the females. The finest white feathers of the female have always their ends a little grayish, which lessens their lustre, and lowers their price. These feathers are imported from Algiers, Tunis, Alexandria, Madagascar, and Senegal; this being the order of their value.

The *scouring process* is thus performed:—4 ounces of white soap, cut small, are dissolved in 4 pounds of water, moderately hot, in a large basin; and the solution is made into a lather by beating with rods. Two bundles of the feathers, tied with packthread, are then introduced, and are rubbed well with the hands for five or six minutes. After this soaping they are washed in clear water, as hot as the hand can bear.

The whitening or bleaching is performed by three successive operations.

1. They are immersed in hot water mixed with Spanish white, and well agitated in it; after which they are washed in three waters in succession.

2. The feathers are azured in cold water containing a little indigo tied up in a fine cloth. They should be passed quickly through this bath.

3. They are sulphured in the same way as straw hats are (See SULPHURING); they are then dried by hanging upon cords, when they must be well shaken from time to time to open the fibres.

The ribs are scraped with a bit of glass cut circularly, in order to render them very pliant. By drawing the edge of a blunt knife over the filaments they assume the curly form so much admired. The hairs of a dingy color are dyed black. For 20 pounds of feathers, a strong decoction is made of 25 pounds of logwood in a proper quantity of water. After boiling it for 6 hours, the wood is taken out, 3 pounds of copperas are thrown in; and, after continuing the ebullition for 15 or 20 minutes, the copper is taken from the fire. The feathers are then immersed by handfuls, thoroughly soaked, and worked about; and left in for two or three days. They are next cleansed in a very weak alkaline ley, and soaped three several times. When they feel very soft to the touch, they must be rinsed in cold water, and afterwards dried. White feathers are very difficult to dye a beautiful black. The acetate of iron is said to answer better than the sulphate, as a mordant.

For dying other colors, the feathers should be previously well bleached by the action of the sun and the dew; the end of the tube being cut sharp like a toothpick, and the feathers being planted singly in the grass. After fifteen days' exposure, they are cleared with soap as above described.

Rose color or *pink*, is given with safflower and lemon juice.

Deep red, by a boiling hot bath of Brazil wood, after aluming.

Crimson. The above deep red feathers are passed through a bath of cudbear.

Prune de Monsieur. The deep red is passed through an alkaline bath.

Blues of every shade, are dyed with the indigo vat.

Yellow; after aluming, with a bath of turmeric or weld.

Other tints may be obtained by a mixture of the above dyes.

Feathers have some more useful employments than the decoration of the heads of women and soldiers. In one case, they supply us with a soft elastic down on which we can repose our wearied frames, and enjoy sweet slumbers. Such are called *bed* feathers. Others are employed for writing, and these are called *quills*.

Goose feathers are most esteemed for beds, and they are best when plucked from the living bird, which is done thrice a year, in spring, midsummer, and the beginning of harvest. The qualities sought for in bed feathers, are softness, elasticity, lightness, and warmth. Their only preparation when cleanly gathered is a slight beating to clear away the loose matter, but for this purpose they must be first well dried either by the sun or a stove. Bleaching with lime water is a bad thing, as they never can be freed from white dust afterwards.

The feathers of the eider duck, *anas mollissima*, called eider down, possess in a superior degree all the good qualities of goose down. It is used only as a covering to beds, and never should be slept upon, as it thereby loses its elasticity

Quills for writing. These consist usually of the feathers plucked out of the wings of geese. Dutch quills have been highly esteemed, as the Dutch were the first who hit upon the art of preparing them well, by clearing them both inside and outside from a fatty humor with which they are naturally impregnated, and which prevents the ink from flowing freely along the pens made with them. The Dutch for a long time employed hot cinders or ashes to attain this end; and their secret was preserved very carefully, but it at length transpired, and the process was then improved. A bath of very fine sand must be kept constantly at a suitable temperature, which is about 140° F.; into this, the quill end of the feather must be plunged, and left in it a few instants. On taking them out they must be strongly rubbed with a piece of flannel, after which they are found to be white and transparent. Both carbonate of potash in solution and dilute sulphuric acid have been tried to effect the same end, but without success. The yellow tint which gives quills the air of age, is produced by dipping them for a little in dilute muriatic acid, and then making them perfectly dry. But this process must be preceded by the sand-bath operation. The above is the French process.

Quills are dressed by the London dealers in two ways; by the one, they remain of their natural color; by the other, they acquire a yellow tint. The former is called the Dutch method, and the principal workman is called a Dutcher. He sits before a small stove fire, into which he thrusts the barrel of the quill for about a second, then lays its root quickly below his blunt-edged knife called a hook, and, pressing this firmly with the left hand, draws the quill briskly through with his right. The bed on which the quill is laid to receive this pressure is called the plate. It is a rectangular smooth lump of iron, about 3 inches long, 1½ broad, and 2½ thick, which is heated on his stove to about the 350th degree Fahr. The hook is a ruler of about 15 inches in length, somewhat like the patten-maker's knife, its fulcrum being formed at the one end by a hook and staple, and the power of pressure being applied by the hand at the other end. The quill, rendered soft and elastic by the heat, endures the strong scraping action of the tool, and thus gets stripped of its opaque outer membrane, without hazard of being split. A skilful workman can pass 2000 quills through his hands in a day of 10 hours.

They are next cleaned by being scrubbed by a woman with a piece of rough dog-fish skin, and finally tied up by a man in one quarter of a hundred bundles.

In another mode of dressing quills, they are steeped a night in decoction of turmeric, to stain them yellow; taken out and dried in warm sand contained in a pot, then scraped by the Dutcher as above described. The first are reckoned to make the best pens, though the second may appear more beautiful.

Crow quills for draughtsmen, as well as swan quills, are prepared in the same way. The quills plucked from well-fed living birds have most elasticity, and are least subject to be moth eaten. The best are those plucked, or which are spontaneously cast in the month of May or June, because they are then fully ripe. In the goose's wing the five exterior feathers only are valuable for writing. The first is the hardest and roundest of all, but the shortest. The next two are the best of the five. They are sorted into those of the right and the left wing, which are differently bent. The heaviest quills are, generally speaking, the best. Lately, steaming for four hours has been proposed as a good preparation.

FECULA (*Fecule*, Fr.; *Stärkemehl*, Germ.) sometimes signifies corn flour, sometimes starch from whatever source obtained.

FELDSPAR (*Orthose*, Fr.; *Feldspath*, Germ.) is a mineral crystallizing in oblique rhomboidal prisms, susceptible of two clivages; lustre more pearly than vitreous; spec. grav. 2·39 to 2·58; scratches glass; yields no water when calcined; fusible at the blowpipe into a white enamel; not affected by acids. The liquid left from its analytical treatment with nitrate of baryta, nitric acid, and carbonate of ammonia, affords on evaporation an alkaline residuum which precipitates platina from its chloride, and appears from this, as well as other tests, to be potash. Feldspar consists of—silica, 66·75; alumina, 17·50; potash, 12; lime, 1·25; oxyde of iron, 0·75. *Rose.* This mineral is a leading constituent of granite; and in its decomposed state furnishes the petuntse or Cornish stone, so much used in the porcelain and best pottery manufactures.

FELTED CLOTH. This woollen fabric, made without spinning and weaving, was made the subject of a patent by Mr. T. R. Williams in February, 1850. A copious description of the process is given in *Newton's Journal*, xxii. 1.

Varnished or Japanned Felt is made by imbuing the stuff of coarse hat bodies with drying oil, prepared by boiling 50 lbs. of linseed oil with white lead, litharge, and umber, of each one pound. The felt is to be dried in a stove, and then polished by pumice-stone. Five or six coats of oil are required. The surface is at last varnished. When the object is intended to be stiff, like visors, the fabric is to be impregnated first of all with flour-paste, then stove-dried, cut into the desired shape, next imbued with the drying-oil, and pumiced repeatedly; lastly placed, to the number of 20, in a hot iron mould, and exposed to strong pressure. Japanned hats, made in this way, are sold in France at 1*s.* 3*d.* a piece; and they will stand several years' wear.

FELTING. (*Feutrage*, Fr.; *Filzen*, Germ.) is the process by which loose flocks of wool, and hairs of various animals, as the beaver, rabbit, hare, &c., are mutually interlaced into a compact textile fabric. The first step toward making felt is to mix, in the proper proportions, the different kinds of fibres intended to form the stuff; and then, by the vibratory strokes of the bowstring, to toss them up in the air, and to cause them to fall as irregularly as possible, upon the table, opened, spread, and scattered. The workman covers this layer of loose flocks with a piece of thick blanket stuff slightly moistened; he presses it with his hands, moving the hairs backward and forward in all directions. Thus the different fibres get interlaced, by their ends pursuing ever tortuous paths; their vermicular motion being always, however, root foremost. As the matting gets denser, the hand pressure should be increased in order to overcome the increasing resistance to the decussation.

A first thin sheet of soft spongy felt being now formed, a second is condensed upon it in like manner, and then a third, till the requisite strength and thickness be obtained. These different pieces are successively brought together disposed in a way suitable to the wished-for article, and united by continued dexterous pressure. The stuff must be next subjected to the fulling-mill. See HAT MANUFACTURE.

FERMENT (Eng. and Fr.; *Hefe*, Germ.) is the substance which, when added in a small quantity to vegetable or animal fluids, tends to excite those intestine motions and changes which accompany fermentation. It seems to be the result of an alteration which vegetable albumen and gluten undergo with contact of air amidst a fermenting mass. The precipitate or lees which fall down when fermentation is finished consist of a mixture of the fermenting principle with the insoluble matters contained in the fermented liquor, some of which, like hordeine, existed in the worts, and others are probably generated at the time.

To prepare a pure ferment, or at least a compound rich in that principle, the precipitate separated during the fermentation of a clear infusion of malt, commonly called yeast or barm, is made use of. This pasty matter must be washed in cold distilled water, drained and squeezed between the folds of blotting paper.. By this treatment it becomes a pulverulent mass, composed of small transparent grains, yellowish gray when viewed in the compound microscope. It contains much water, and is therefore soft, like moist gluten and albumen. When dried, it becomes like these bodies, translucid, yellowish brown, horny, hard, and brittle. In the soft humid state it is insipid, inodorous, insoluble in water and alcohol. If, in this state, the *ferment* be left to itself at a temperature of from 60° to 70° F., but not in too dry a situation, it putrefies with the same phenomena as vegetable gluten and albumen, and leaves, like them, a residuum resembling old cheese.

At the beginning of this change, particularly if the ferment be enclosed in a limited portion of air, there is an absorption of oxygen gas with a fivefold disengagement of carbonic acid gas; while acetic acid makes its appearance in the substance. When distilled by itself it affords the same products as gluten. Dilute acids dissolve it very readily; and so does potash with the production of ammonia, a peculiar circumstance, for in dissolving gluten the alkali causes no such evolution.

The property possessed by yeast of determining the fermentation of a properly diluted solution of sugar is very fleeting, and is lost by very trifling alterations. It is destroyed by complete desiccation, and cannot be restored by moistening it again. The attempts made in London to squeeze out the liquid part of yeast in bags placed in a powerful press, and to obtain a solid cake, in order to transport ferment to India, have had but a very partial success; for its virtue is so impaired that it will rarely excite a perfect fermentation in the best prepared worts. The same method is adopted in Germany, to send yeast to only moderate distances; and therefore with more advantage.

If yeast be boiled for ten minutes, it loses the greater part of its fermenting power, and by longer boiling it becomes inert.

When alcohol is poured upon yeast, it immediately destroys its fermenting faculties, though, on filtering it off, it seems to carry no remarkable principle with it. One thousandth part of sulphuric acid equally deprives yeast of its peculiar property, and so does a little strong acetic acid. All the acids and the salts, especially those which part readily with their oxygen, produce the same effect. A very small quantity of sulphurous acid, or sulphites, mustard powder, particularly the volatile oil of mustard, and in general the volatile oils that contain sulphur, as well as the vegetables which yield them, such as horse-radish and garlic, all kill the fermenting agent. Lastly, fermentation is completely stopped by a moderate depression of temperature.

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During fermentation the yeast undergoes a change; it loses the property of causing another wort to ferment. This change probably depends upon the chemical reaction between the ferment and the sugar that is decomposed; for a certain quantity of yeast can effect the fermentation of only a certain quantity of sugar, and all the sugar exceeding this quantity remains unaltered in the liquor. It has been concluded from some rather loose experiments, that one part and a half of yeast (supposed to be in the dry state), is adequate to the fermentation of a solution of 100 parts of pure sugar. When such a solution is fermented by the precise proportion of yeast, the fermenting principle is exhausted, for no new yeast is formed in it. There is a deposit indeed to about half the weight of the yeast employed, of a white matter insoluble in water. which affords no ammonia by dry distillation, and is incapable of acting as a ferment upon a fresh saccharine solution.

Of all the bodies convertible into yeast during fermentation, vegetable gluten and albumen possess the most rapid and energetic powers. But ordinary glue, isinglass, animal fibrine, curd or *caseum*, albumine, urine, and other azotized substances, all enjoy the property of causing a solution of sugar to ferment; with this difference, that whilst yeast can establish a complete fermentation in less than an hour, at a temperature of about 68°, the above substances require several days, with a heat of from 77° to 87° F., for becoming ferments, and for occasioning fermentation. Substances devoid of nitrogen do not produce a ferment.

FERMENTATION. (Eng. and Fr.; *Gahrung*, Germ.) When organic substances, under the influence of water, air, and warmth, are abandoned to the reciprocal operation of their proximate principles (sugar, starch, gluten, &c.), they are entirely changed and decomposed, so that their ultimate principles (oxygen, hydrogen, carbon, and in some cases azote) combine in new proportions, and thus give birth to various new compounds. To this process, the general name of fermentation has been given. These operations and their products differ according to the differences of the substances, and of the circumstances in which they are placed. The following may be enumerated as sufficiently distinct species of fermentation. 1. The *saccharine* fermentation, in which starch and gum are changed into sugar. 2. The *vinous* fermentation, in which sugar is converted into alcohol. 3. The *mucilaginous* fermentation, in which sugar is converted into slime, instead of alcohol. 4. The *acetous* fermentation, in which alcohol and other substances are converted into vinegar. 5. The putrid fermentation or putrefaction, which characterizes particularly the decomposition of azotized organic substances.

1. *The saccharine fermentation.* When a paste made by boiling one part of starch with twelve parts of water is left entirely to itself, water merely being stirred in as it evaporates, at the end of a month or two in summer weather it is changed into sugar, equal in weight to from one third to one half of the starch, and into gum, equal to from one fifth to one tenth, with a residuum of starch paste somewhat altered. This saccharifying process advances much quicker through the co-operation of vegetable albumine or gluten, acting as a ferment. If we boil two parts of potato starch into a paste with twenty parts of water, mix this paste with one part of the gluten of wheat flour, and set the mixture for 8 hours in a temperature of from 122° to 167° F., the mixture soon loses its pasty character, and becomes by degrees limpid, transparent, and sweet, passing at the same time first into gum, and then into sugar. The remainder consists of the unchanged starch with the altered gluten, which has become sour, and has lost the faculty of acting upon fresh portions of starch. It is probable, however, that the sugar formation in the first case, when the starch undergoes a spontaneous change, may be due to the action of a small portion of gluten and albumine left in the starch, since a putrefactive smell is eventually evolved indicative of that azotized matter. The gum into which during this process the starch is first converted, and which becomes afterwards sugar, is of the same nature as British gum, formed by the roasting of starch.

This production of sugar takes place in the germination and kiln-drying of malt; and the mashing of the brewer as well as the sweetening of bread in baking, rests upon the same principles. In many cases the vinous fermentation precedes the saccharification, or accompanies it; the starchy parts of the fermenting mass changing into sugar, while the previously formed sugar becomes wine or beer. In the sweetening of fruits by keeping, a similar process occurs; the gummy and starchy fibres become sugar from the action of the glutinous ferment which they contain; as happens also to the juices of many fruits which sweeten for a little while after they have been expressed.

The nature of this sugar formation through the influence of gluten upon starch, is undoubtedly the same as the conversion of starch into sugar, by boiling it with sulphuric acid; though the whole theory of this change is not entirely developed.

The most energetic substance for the conversion of starch into sugar, is the malt of barley. According to the researches of Payen and Persoz, the gum which by this process is first formed, may be prevented from going into sugar, by merely exposing it to a boiling heat, and hence we have it in our power either to make sugar or gum at pleasure. Of finely ground malt from 10 to 25 parts must be taken for 100 parts of starch. Into a pan placed in a water bath, 400 parts of water being warmed to from 77° to 86° F., the ground malt must be stirred in, and the temperature must be raised to 140°. The 100 parts of starch must now be added, and well mixed. The heat is then to be increased to 158° F.; and be so regulated that it shall not fall below 149°, nor rise above 167°. In the course of 20 or 30 minutes the originally milky and pasty liquid will become gradually more attenuated, and eventually it will turn as fluid nearly as water. This is the point of time in which the starch has passed into gum, or into the substance lately denominated *dextrine* by the chemists. Should this mucilaginous matter, which appears to be a mixture of gum and a little starchy sugar, be wished for in that state, the temperature of the liquid must be suddenly raised to the boiling point, whereby the further action of the malt upon it is stopped. But on the other hand, if sugar be desired, then the temperature must be steadily maintained at from 158° to 167° for three quarters of an hour, in which time the greater part of the starch will have become sugar, and from the evaporation of the fluid a starchy syrup will be obtained, entirely similar to that procurable by the action of very dilute sulphuric acid upon starch.

The substance which operates this saccharine change, or the appropriate yeast of the sugar fermentation, which had been previously imagined to be a residuum of gluten or vegetable albumen in the germinated grain, has been traced by Payen and Persoz to a peculiar proximate vegetable principle called by them *diastase*. This substance is generated during the germination of barley, oats, and wheat, and may be obtained separately by infusing the ground malt in a small quantity of cold water, straining off the liquor, then filtering it, and heating the clear solution in a water-bath to the temperature of 158° F. The greater part of the vegetable albumen is thus coagulated, and must be separated by a fresh filtration; the liquid is afterwards treated with alcohol as long as the flocculent precipitate of diastase falls. In order to purify it still more completely from the azotized matter, it may be once more dissolved in water, and again precipitated by alcohol. When dried at a low temperature, it appears as a white solid, which contains no azote, is insoluble in strong alcohol, but dissolves in weak alcohol and water. Its solution is neutral and tasteless; and if left to itself, it changes spontaneously, sooner or later, according to the degree of warmth, and becomes sour. At the temperature of from 149° to 168°, it has the property of converting starch into gum or dextrine, and sugar; and, when sufficiently pure, it does this with such energy, that one part of it is capable of saccharifying 2000 parts of dry starch. It acts the more rapidly the larger its proportion. Whenever the solution of diastase with starch or dextrine has been heated to the boiling point, it loses the property of transforming these substances. One hundred parts of well malted barley appear to contain about one part of this new body.

2. *The Vinous Fermentation.*—In this fermentation the sugar existing in watery solution is, by the operation of the ferment or yeast, converted into alcohol, with disengagement of carbonic acid gas. If we dissolve one part of pure sugar in ten parts of water, and leave the solution in a temperature of from 68° to 77° F., which is that most favorable to fermentation, it will remain unaltered. But if we stir into that solution some beer yeast, the phenomena of fermentation soon appear in the above circumstances; for carbonic acid gas is evolved, with intestine movements of the liquid, and an increase of its temperature. A body of yeast rises to the surface, and exhibits a continual formation and rupture of air bubbles. At length the sugar being in a great measure decomposed, the motions cease, the liquor becomes clear, and instead of being a sirup, it is now a dilute alcohol. The yeast has by this time fallen to the bottom in a somewhat compact form, and of a whitish color, deprived of the property of exciting fermentation in fresh sirup, provided no undue excess of it was added at first, for that alone would remain effective. Experience shows that for the conversion of a determinate quantity of sugar by fermentation, a determinate quantity of yeast is necessary, which has been estimated at about 1½ per cent. in the dry state. When the yeast has been decomposed by fermenting its definite proportion of sugar, it loses its fermentable property, and leaves the excess of sugar unaffected, forming a sweet vinous solution. The same thing happens if the yeast be separated from the wort by a filter in the progress of the fermentation, for then all intestine motion speedily stops, although much saccharine matter remains.

In the juices of sweet fruits, of grapes, for example, the ferment is intimately associated with the sugar. It is at first soluble and inactive, till it absorbs oxygen from the atmosphere, whereby it becomes an operative ferment, but, at the same time, insoluble, so as to precipitate at the end of the process. When the expressed juice of the grape, or *must*, is enclosed in a vessel out of contact of air, and there subjected to the heat of boiling water, the small portion of oxygen present is rendered inactive and the liquor experiences no fermentative change. If the grapes be squeezed in an atmosphere deprived of oxygen, and confined in the same, the juice will also remain unaltered. Recently expressed grape juice is limpid, and manifests the commencement of fermentation by the separation of the yeasty substance, which can take place only with access of air. The solution becomes turbid after a certain time, gas begins to be evolved, and the separated ferment decomposes the sugar. At the end of the process the yeast collects at the bottom of the vessel, usually in larger quantity than was sufficient to complete the fermentation; and hence a considerable portion of it possesses still the fermentative faculty. The fermentation itself, when once begun, that is, whenever the yeasty particles are evolved and float in the liquid, for which evolution a very minute quantity of oxygen is sufficient, is thenceforth independent of the contact of air, and goes on as well in close as in open vessels; so that the production of alcohol and carbonic acid depends solely upon the mutual reaction of the ferment and the sugar.

The yeast, which may be obtained tolerably pure from a fine infusion of malt in a state of fermentation, after being washed with cold water to separate the soluble, gummy, and saccharine matter, and after being pressed between folds of blotting paper, constitutes a pulverulent, grayish yellow, granular substance, destitute of both taste and smell, insoluble both in water and alcohol. Cold water dissolves, indeed, only $\frac{1}{100}$, and boiling water very little more.

The essentially operative constituent of yeast is a peculiar azotized matter, which in the wine vat is mixed with some tartar and other salts, and in the beer tun with gum, starch, &c. This animalized substance may be obtained in a separate state, according to Braconnot, by acting upon the washed yeast powder with a weak ley of carbonate of potash, and by decomposing the solution with vinegar, whereby the matter is thrown down in a gelatinous form. The substance thus obtained is insoluble in cold water and alcohol, but dissolves readily in very dilute alkaline leys, and even in lime water. When diffused through water, it assumes a homogeneous aspect, as if it were really dissolved; but when this mixture is heated, the animalized matter coagulates, and separates in thick flocks. In this state it has lost its former properties, being no longer soluble in alkaline leys, even when concentrated. Acids exercise no solvent power over this peculiar matter; they precipitate it from its solutions, as do also the earthy and metallic salts, which, moreover, combine with it. This is also the case with tannin. The combination of the ferment stuff with acids increases the stability of its constitution, and counteracts its tendency to influence solutions of sugar. These properties of the operative principle of yeast explain many of the phenomena of fermentation, as we shall presently see.

The animalized matter of yeast resembles gluten, albumen, caseum, and other azotized substances; if any one of these be put into a saccharine solution ready for fermentation, it will begin to operate a change, when aided by warmth and time, if it be previously decomposed in some measure to facilitate its influence; or if these substances be brought into a slightly putrescent state beforehand, they will cause more speedy fermentation. Thus white of egg, when added to saccharine liquors, requires a period of three weeks, with a temperature of 96° F., before it will excite fermentation; afterwards the excess of the albumen forms a precipitate which may be used instead of yeast upon other sweet worts. The rapidity with which such azotized substances are capable of being converted into ferments of more or less purity and power is very variable; vegetable gluten and albumen being best fitted for this purpose. This conversion is accelerated when the sweet liquor in which the substance is diffused or dissolved has already begun to ferment; whence it appears that the presence of carbonic acid gas, combined with the liquor, is here of singular influence. Upon it, in fact, the formation and elimination of the yeast in fermenting liquors depend.

A solution of pure sugar, which has been made to ferment by the addition of yeast, furnishes no new yeast; but there remains after the process a portion of the yeast originally mixed, in an altered inoperative condition, should its quantity have been exactly adequate to the decomposition of the sugar, or in an operative state, should the quantity have been originally excessive.

But if the fermentable liquor contains vegetable albumen and gluten, as is commonly the case with the sweet juices of fruits and beer worts, these substances become changed into ferments in the course of the fermentation induced by the yeast, and, being superfluous, so to speak, for that particular process, they remain entire at the end, and may be collected for use in other operations.

Upon this principle is founded the increased production of yeast, and the manufacture of what has been called *artificial barm*, in which the fermentation is conducted chiefly with a view to the formation of yeast. To the fermenting mass, those kinds of meal are added, which abound in albumen and gluten, as barley, beans, or wheat, for instance;

and the process is similar to the production of a great lump of leaven, from the action of a small piece of it upon dough. The following prescription will illustrate this subject. Take three ounces of bean flour, add to it five quarts of boiling water, and boil the mixture for half an hour. Pour the decoction into a vessel, and stir into it, while hot, 56 ounces of wheaten flour. After the mixture cools to the temperature of 54° F., add to it about two quarts of beer barm, stirring the whole well together. About 24 hours after the commencement of the fermentation, incorporate with the mixture 112 ounces of barley or bean flour, till it becomes a uniform dough, which must be thoroughly kneaded, rolled out into cakes about an inch thick, and cut into pieces of the size of a dollar. These cakelets must be dried upon laths in the sun in favorable weather, and then put up in a dry situation. For use, one of these discs is to be broken into pieces, laid in warm water, and set in a warm place during 12 hours. The soft mass will then serve the purpose of beer yeast.

Or we may mix equal parts of barley malt, wheat malt, and crushed rye, pour water at the temperature of 122° F. over them into a tub till it stand a span above their surface; then stir well together, and allow the whole to remain at rest for a few hours, till it cools to about 65° F. We must now add for each pound of the mingled meals, a quarter of an ounce of beer barm. The tub must be then covered, and preserved at a temperature of 63° F. The husks, as they begin to rise to the surface, in consequence of the fermentation, must be taken off and squeezed through a cloth over the vessel. When the meal comes afterwards to subside to the bottom, the whole must be strained through a canvass bag, and freed from the superfluous moisture by squeezing. The bag with its doughy mass must next be surrounded with dry ashes, to remove the remaining humidity, and to arrest any further fermentation. This consistent ferment may be used instead of beer yeast.

It is difficult to prepare an artificial yeast without barm. The best process for this purpose is the following. Take five parts of honey, one part of powdered tartar, and sixteen parts of wheat or barley malt, stir the whole in water of the temperature of 122° F., and place in a fermenting heat; when the yeast will, as usual, be eliminated.

The change which gluten or vegetable albumen undergoes in the different kinds of meal, when it becomes a ferment, consists apparently in an oxydation, since analysis shows that this ferment contains more oxygen than gluten does.

It has been already stated that yeast in its liquid condition readily putrefies, and becomes altogether useless for the process of fermentation. In order to preserve it for some time, it must be dried to such a degree as to resist spontaneous decomposition without losing its fermentative faculty; but completely dried yeast loses that property, and does not recover it by being again moistened. Beer barm may be dried after being washed several times with cold water, till the last quantity comes off clear; but the insoluble portion must be allowed to settle fully before the water is poured away from it. The residuum being freed as much as possible from water, by drainage and pressure between flannel cloths, is to be dried in the shade by a current of warm air as quickly as possible, with the aid of frequent turning over. It must be afterwards kept in dry earthen vessels. Yeast may also be preserved a short time in activity by being kneaded with as much barley or wheat flour as it can take up without losing the doughy consistence. Dried yeast has, however, always an impaired activity. The easiest and most certain method of preserving yeast in its primitive power, is by mixing it, after pressure in flannel, with as much pulverized sugar as will render it dry, and putting up the mixture in air-tight vessels. The fermentative power of yeast is destroyed by the following means: 1. as already stated, by making it completely dry either by the evaporation of the water, or its abstraction by alcohol; 2. by boiling, which if continued for ten minutes renders yeast quite inoperative; 3. by the action of such substances as dissolve out its essential constituents; by alkalis, for instance, since the particles of yeast seem to be operative only in their insoluble granular state; 4. by such substances as form combinations with it, and thereby either alter its nature, or at least increase the cohesion of its constituent parts, so that they can no longer operate upon sweet liquors by the decomposing affinity of its ultimate particles. Such bodies are the acids, especially the mineral ones, tannin and most salts, particularly the metallic, which unite with the yeast into new compounds. The volatile oils which contain sulphur exercise the same paralyzing influence upon yeast.

The circumstances which promote, and are necessary to, the vinous fermentation are, conformably to the above views, the following:—1. The presence of the proper quantity of active yeast, and its proper distribution through the worts. If in the course of a slack fermentation the yeast subsides to the bottom, the intestine motions cease entirely, but they may be excited anew by stirring up the ingredients, or rousing the tun, as the brewers say. 2. A certain degree of warmth, which should never be less than 51° F., nor more than 86°; the temperature of from 68° to 77° being the most propitious for the commencement and progress of fermentation. When other circumstances are the same, the rapidity of the fermentation is proportional to the temperature within certain limits, so that, by lowering it, the action may be moderated at pleasure. 3. The fermentation proceeds the better and more equably the greater the mass of fermenting liquor, probably on account of the uniformly high temperature, as well as the uniform distribution of the active particles of the yeast by the greater energy of the intestine movements. 4. The saccharine solution must be sufficiently diluted with water; when too much concentrated it will not ferment. Hence very sweet musts furnish wines containing much undecomposed sugar. For a complete fermentative action, one part of sugar should be dissolved in ten parts of water.

Fermentation may be tempered or stopped: 1. by those means which render the yeast inoperative, particularly by the oils that contain sulphur, as oil of mustard; as also by the sulphurous and sulphuric acids. The operation of the sulphurous acid in obstructing the fermentation of must consists partly, no doubt, in its absorbing oxygen, whereby the elimination of the yeasty particles is prevented. The sulphurous acid, moreover, acts more powerfully upon fermenting liquors that contain tartar, as grape juice, than sulphuric acid. This acid decomposes the tartaric salts, and combining with their bases, sets the vegetable acid free, which does not interfere with the fermentation; but the sulphurous acid operates directly upon the yeast: 2, by the separation of the yeast, either with the filter or by subsidence; 3, by lowering the temperature to 45° F. If the fermenting mass become clear at this temperature, and be drawn off from the subsided yeast, it will not ferment again, though it should be heated to the proper pitch.

The products of vinous fermentation are carbonic acid gas, and alcohol; of which the former escapes during the process, except in the case of the sparkling wines, like champaign, that are partially fermented in close vessels. The alcohol remains in the fermented liquor. 100 parts of sugar afford by complete decomposition nearly 50 parts of alcohol. According to Thenard, 100 parts of sugar are converted into 46·8 parts of carbonic acid, and 49·38 of alcohol; besides 3·82 parts of carbon otherwise employed, which the sugar contained, above what is present in the former two products. This chemist found in the fermented liquor 4 per cent. of an extractive matter, soluble in water, and having an acidulous reaction, to whose formation, probably, that excess of carbon may be necessary. In what way the action of the yeasty particles upon the saccharine substance is carried on in the vinous fermentation, or what may be the interior working of this process, is not accurately understood. The quantitative relation of the carbonic acid and alcohol to the sugar is pretty well made out; but the determination of the ultimate principles of the ferment itself, before and after the vinous change, and of the residuum dissolved in the fermented liquor, has not been well ascertained. It is probable that the yeast undergoes in the process a similar decomposition to that of the putrefactive, and that its elementary constituents enter into new combinations, and abstract so much carbon and hydrogen from the sugar, that the remainder, amounting to 96 per cent. of the whole, may constitute one atom of alcohol and one of carbonic acid.

3. *The slimy or glutinous fermentation.*—This process takes place in weak solutions of sugar, at ordinary fermenting temperatures, where, from defect of good yeast, the vinous fermentation cannot proceed. In such circumstances, from one part of sugar, one third part of gum is formed. According to Desfosses, however, 100 parts of sugar afford 109·48 of gum or slime. This is formed when one part of sugar is dissolved in twenty parts of water, which had been previously boiled with washed barm or gluten, and then filtered. The process proceeds slowly and quietly, equally well in close vessels, as with contact of air, and continues at ordinary temperatures about 12 days; but it goes on more rapidly and completely at the heat of from 77° to 86° F. A small quantity of hydrogen and carbonic acid gas is disengaged, in the proportion of two to one by volume. The fermented liquor becomes turbid, and assumes a tough thready appearance, like a decoction of linseed. A small addition of sulphuric or sulphurous acid, of muriatic acid and alum, or of tannin, impedes this species of fermentation; because these substances combine, as in the vinous fermentation, with the ferment into an insoluble precipitate, unsusceptible of further change. In many wines, especially when bottled, this slimy fermentation occurs, and occasions their ropiness, which may be best remedied or prevented by the addition of as much tannin as will precipitate the dissolved mucous matter. This species of fermentation attacks very rapidly the rinsing waters of the sugar refiner, which always contain some fermentative gluten. A little alum is the best preventive in this case, because it precipitates the dissolved ferment.

4. *The acetous or sour fermentation.*—In this process, alcohol, more or less dilute, is resolved into water and vinegar in consequence of the operation of the ferment; oxy-

dizement of the alcohol being effected by the oxygen of the atmospherical air. The requisites of this process have been already detailed under the article Acetic Acid. They are, the presence of atmospherical air; alcohol diluted to a certain degree with water ferment or yeast, and a temperature above 66° F. The most active ferments are such substances as have already passed into the acetous state; hence vinegar, especially when it contains some yeasty particles, or is combined with porous and spongy bodies, so as to multiply its points of contact with the vinous liquor, is particularly powerful. Common yeast may also be employed for vinegar ferments, if it be imbued with a little vinegar, with leaven, crusts of bread soaked in vinegar, the stalks and husks of grapes, sawdust and shavings of beech or oak impregnated with vinegar, or the slimy sediment of vinegar casks called *mother;* all of which operate as ferments chiefly in consequence of the vinegar which they contain. The inside shavings of the staves of vinegar tuns act on the same principle.

The acetous fermentation may, moreover, go on along with the vinous in the same liquor, when this contains sugar as well as alcohol. Whilst the acidification of the alcohol is effected by the absorption of oxygen from the atmosphere, the sugar becomes alcohol with disengagement of carbonic acid, and then passes into vinegar. Since most liquors intended for making vinegar, such as wine, juices of fruits, ales, &c., contain still a little sugar, they disengage always a little carbonic acid. Besides spirits, some other substances, such as gum, the mucilage of plants, and starch paste, directly ferment into vinegar. Sugar also seems to be convertible into vinegar without any vinous change. The albuminous matter of potato juice, precipitated by vinegar, serves as a proper ferment for that purpose, when added in its moist state to weak sirup. 5. See Putrefaction.

Mr. William Black, in his treatise on Brewing, has, with much ingenuity and apparent truth, endeavored to show that the process of fermentation is strongly influenced by electricity, not only that of the atmosphere, as has been long known from the circumstance of beer and wine becoming speedily sour after thunderstorms, but the voltaic, produced by electric combinations of metals in the fermenting tuns. He therefore recommends these tuns to be made with as little metallic work as possible, and to be insulated from the floor of the brewhouse. For the propriety of this advice he adduces some striking examples. Wort which had become stationary in its fermentation, on being pumped out of square gyles imbedded in the floor, into casks placed upon wooden stillions, began immediately to work very well, and gained about 6 degrees of attenuation while throwing off its yeast. From the stagnation of the process in the gyles, he had in the morning predicted an approaching thunderstorm, which accordingly supervened in the course of the evening. In further support of his views he instances the fact, that, in dairies where the milk is put into porcelain vessels, and placed upon wooden shelves, it is seldom injured by lightning; but when contained in wooden or leaden vessels, and placed upon the ground, it almost invariably turns sour in thundery weather. His general conclusion is, "that the preservation or destruction of beer depends upon electricity; and the most certain mode of preservation is to insulate as much as possible, both the squares and all other utensils or vessels connected with the brewing or storing of beer."

Mr. Black further considers that unsoundness of worts is often the result of electricity excited between the mash tun and the copper.

Why is beer liable to get spoiled in thunder-storms, though apparently well insulated in glass bottles?

I shall conclude this article with Mr. Black's description of the phenomena of beer fermentation. In every regular process there are five distinct stages. In the first we see a substance like cream forming all round the edges of the gyle tun; which extends towards the centre until the whole is creamed over, constituting the first change. Next a fine curl appears like cauliflower, which also spreads over the square surface, and according to the strength and appearance of this curl, the quality of the fermentation may be predicated. This he calls the second stage. What is technically called the *stomach* or vinous vapor now begins to be smelt, and continues to gain strength till the process is concluded. From the vinous energy of this odor, and the progressive attenuation of the wort, the vigor of the fermentation may be inferred. The experienced brewer is much guided in his operations by the peculiarity of this effluvium. The third change is when the cauliflower or curling top rises to a fine rocky or light yeasty head; and when this falls down, the fourth stage has arrived. Finally the head should rise to what is called close yeasty, having the appearance of yeast all over. About this period the gas becomes so powerful as to puff up occasionally in little bells or bladders about the size of a walnut, which immediately break. The bells should appear bright and clear. If they be opaque or whey colored, there is some unsoundness in the wort. The great

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point is to add just so much yeast as to carry the fermentation completely through these five changes at the regular periods.

The term fermentation has been of late extended to several operations besides those formerly included under it. The phenomena which it exhibits under these different phases and the changes which it effects among the various subjects of its operations, are no less striking and mysterious in their principle than important in their application to the arts of life. Fermentations are now arranged into twelve classes—1, the alcoholic; 2, the glucosic or saccharine; 3, the viscous or mucous; 4, the lactic; 5, the ascetic; 6, the gallic; 7, the pectic; 8, the benzoilic; 9, the sinapic; 10, the ammoniacal; 11, the putrid; and 12, the fatty.

Fermentation, in the most general sense, may be defined to be a spontaneous reaction, a chemical metamorphosis, excited in a mass of organic matter by the mere presence of another substance, which neither extracts from, nor gives to, the matter which it decomposes any thing whatever. This process requires the following conditions:—1. A temperature from 45° to 90° F.; 2. Water; 3. The contact of air; 4. The presence of a neutral organic azotized matter, in a very small quantity, and of a crystallizable non-azotized substance, in considerable quantity. The former is the ferment, the latter undergoes fermentation. In ordinary chemical actions we perceive one body unite to another to form a new compound; or one body turn another out of a combination, and take its place, in virtue of a superior affinity. These effects are foreseen and explained by the intervention of that molecular force which governs all chemical operations, that attractive power which unites the particles of dissimilar bodies. Thus, also, in the ordinary phenomena of decomposition, we perceive the agency of heat at one time, at another of light, or of electricity; forces of which, though we are not acquainted with the essence, yet we know the exact effect under determinate circumstances. But fermentation, on the contrary, can be explained neither by the known laws of chemical affinity nor by the intervention of the powers of light, electricity, or heat. Fermentation reduces complex organic substances to simpler compounds, thereby reducing them nearer to the constitution of mineral nature. It is an operation analogous, in some respects, to that effected by animals upon their vegetable food.

With a good microscope, any person may convince himself that ferment or yeast is an organized matter, formed entirely of globules, or of corpuscles slightly ovoid, from the three to the four thousandth part of an inch in diameter. Sometimes their surface seems to have a little tail, which has been regarded as a bud or germ attached to the mother cell. Whenever the fermentation begins, the yeast does not remain an instant idle. These small round bodies become agitated in all directions, and if the substance undergoing fermentation is mixed with an azotized matter, as in beer-worts, the corpuscles become larger, the small tails get developed, and on acquiring a certain size they separate from the parent globule, to live by themselves and give birth to new corpuscles.* In the fermentation of beer from malt, this series of multiplications produces a quantity of yeast seven times greater than what was added at the commencement. Were the above ingenious speculations demonstrated with certainty, we should be led to admit, in all these phenomena, actions truly vital, and a reproduction like that of buds in the vegetable kingdom. The existence of a vital force seems to be rendered probable by the fact that in incomplete fermentation, such as that of fine syrup with too little yeast, the ferment loses its properties and powers. If, however, we add to the solution of pure sugar an albuminous substance, a caseous or fleshy matter, the development of yeast becomes manifest, and an additional quantity of it is found at the end of the operation. Thus with nourishment, ferment engenders ferment. It is for this reason that a little fermenting must, added to a body of fresh grape-juice, excites fermentation in the whole mass. These effects are not confined to alcoholic fermentation. The smallest portions of sour milk, of sour dough, or sour juice of beet-root, of putrefied flesh or blood, occasion like alterations in fresh milk, dough, juice of beet-roots, flesh, and blood. But further, and which is a very curious circumstance, if we put into a liquid containing any fermenting substance, another in a sound state, the latter would suffer decomposition under the influence of the former. If we place urea in presence of beer-yeast, it experiences no change; while if we add to it sugar-water in a fermenting state, the urea is converted into carbonate of ammonia. We thus possess two modes of decomposition, the one direct, the other indirect.

Although yeast has all the appearances of an organized substance, it is merely by analogy that its multiplication by growth is assumed, for this is a phenomenon very difficult of experimental demonstration. When blood, cerebral substance, gall, pus, and such like substances, in a putrid state, are laid upon fresh wounds in animals, vomiting, de-

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* M. Turpin, M. Cagniard Latour, M. Quévenne, and Professor Mitscherlich.

debility, and death soon supervene. The scratches from bones in putrid bodies have been often the causes of disease and death to anatomists. The poison in bad sausages is of the same class of ferments. In Wurtemberg, where sausages are prepared from very miscellaneous matters, as blood, livers, brains, and offal of many other kinds, with bread, meal, salt, and spices, fatal results from eating them are not uncommon. Death in these cases is preceded by the gradual wasting of the muscular fibre, and of all the like constituents of the human body; so that the patient becomes emaciated, dries into a complete mummy, and soon expires. The cadaver is stiff as if frozen, and is not subject to putrefaction. During the progress of the *sausage* disease, the saliva becomes viscid, and emits an offensive smell. No peculiar poison can be detected by analysis in the sausages; but they are rendered wholesome food for animals by the action of alcohol, or by that of boiling water, which destroy the noxious *fomes* without acquiring it themselves; and thus decompose the putrefactive ferment of the sausages. When this, however, passes unchanged through the stomach into the circulating system, it imparts its peculiar action to the constituents of the blood, operating upon it as yeast does upon wort. Poisons of a like kind are produced by the body itself in some diseases. In plague, small-pox, measles, &c., substances of a peculiar fermentative nature are generated from the blood, which are capable of inducing in the blood of a healthy person a decomposition like that of which themselves are the subjects. The morbid virus reproduces itself, and multiplies indefinitely, just as the particles of yeast do in the fermentation of beer. The temperature of boiling water, and alcohol applied to matters imbued with such poisonous secretions, renders their poison inert. Many acids, chlorine, iodine, bromine, empyreumatic oils, smoke, creosote, strong decoction of coffee, have the same salutary effect. All these agents are known to counteract fermentation, putrefaction, and that dry wasting of organic matter called *eremacausis*, or *slow combustion*. It is most deserving of remark that the poisons chemically neutral or alkaline, such as those of small-pox in man, and of *typhus ruminantium* in cows, lose their baneful power when subjected to the action of the stomach; whereas that of bad sausages, which is acid, resists the modifying power of the digestive organs.

Alcoholic fermentation has been copiously discussed in the *Dictionary*. I may here add that ammonia, being a product of that change in solution of pure sugar, proves the presence of azote in the yeast; and that sulphuretted hydrogen, being made manifest in the disengaged gaseous products, by their blackening paper imbued with acetate of lead, proves the presence of sulphur. The acid liquor accompanying yeast may be washed away, without impairing materially its fermenting power, while the acid so removed has of itself no such virtue.

Yeast, freed from all soluble matters by water, alcohol, and ether, contains, independently of ashes—carbon, 50·6; hydrogen, 7·3; azote, 15; oxygen, sulphur, and phosphorous, 27·1, in 100 parts. Viewed atomically, yeast bears a close analogy to albumen. Like albuminous matter, yeast takes a violet tint with muriatic acid, and it may be replaced as ferment by gluten. Caseum (the curd of milk) and flesh operate the same effect. All these fermentative powers have the same globular appearance in the microscope with yeast. When the activity of yeast has been destroyed by heat, &c., it can be restored by the positive energy of the voltaic battery, which causes its combination with oxygen. The best proportion of sugar and water, for exhibiting the phenomena of fermentation, is 1 of the former to 3 or 4 of the latter, and 5 parts of sugar to 1 of fresh yeast may be added; though in the course of fermentation, 100 parts of sugar do not consume 2 parts of yeast, estimated in the dry state. The quickest fermenting temperature is from 68° to 86°. A very little oil of turpentine or creosote, or of the mineral acids, prevents or stops fermentation completely; oxalic and prussic acids have the same effect, as also corrosive sublimate and verdigris. It has been known from time immemorial in Burgundy, that a little red precipitate of mercury, when added to the must-tun, stopped the fermentation. All alkalies counteract fermentation, but when they are saturated it recommences. The first person who described the microscopic globules of yeast with precision was Désmazières, who arranged them among the mycodermes (*fungus-skinned*), under the name of *mycoderma cerevisiæ*. They have not the flattened form of the globules of blood, but are rather egg-shaped. One small black point may be seen on their surface, which, after some days, is associated with 3, 4, or 5 others. Their average diameter is from $\frac{1}{5000}$ to $\frac{1}{4000}$ of an inch. Sometimes more minute globules cluster round one of ordinary size, and whirl about with it, when the liquor in which the globules float is agitated.

Fresh yeast loses, by drying, 68 parts in the 100, and becomes solid, horny-looking, and semitransparent, breaking readily into gray or reddish fragments. With water, it resumes immediately its pristine appearance. When fresh yeast is triturated with its own weight of white sugar, it forms a liquid possessing the fluidity of oil of almonds and a yellow color. The globules continue unchanged, except perhaps becoming somewhat smaller. Yeast in the dry state retains its fermentative virtue for a long time.

Saccharine Fermentation is that by which starch and dextrine are converted into sugar, as shown remarkably in the action of diastase upon these bodies. If we mix 2 parts of starch paste with 1 part of dry gluten, and keep the mixture at a temperature of from 122° to 140° Fahr., we obtain a good deal of sugar and dextrine. Some lactic acid is also formed. Flour paste, long kept, spontaneously produces sugar by a like reaction. *See* FERMENTATION in the Dictionary.

Lactic Fermentation.—Almost all azotized organic matters, after being modified by the contact of air, become capable of giving rise to this fermentation. Oxygen does not come into play, except as the means of transforming the animal substances into a ferment. Diastase and caseum are well adapted to exhibit this change. The body that is to furnish the lactic acid may be any one of the neutral vegetable matters, possessing a like composition with lactic acid, such as cane-sugar, grape or potato sugar, dextrine, and sugar of milk. All the agents which stop the alcoholic, stop also the lactic fermentation; while diastase and caseum are its two best exciters. For producing abundance of lactic acid, we have merely to moisten malt, to expose it to the air for a few days, then to triturate it with a quantity of water, and leave the emulsion for some days more in the air, at a temperature between 67° and 86° F. We then saturate the liquor with chalk, after having filtered it, and thereby obtain the lactate of lime which may be crystallized in alcohol, to deprive it of the dextrine and earthy phosphates; and then decomposed by sulphuric acid.

Lactic Acid, formed from curd (caseum), exhibits more remarkable phenomena. Thus when milk is left alone for some time it becomes sour, and coagulates. The coagulum is formed of caseum and butter; while the whey of it contains sugar of milk and some salts. The coagulation of the caseum has been occasioned by the lactic acid, which was generated in consequence of an action which the caseum itself exercised upon the sugar of milk. Thus with the concourse of air, the caseum becomes a ferment, and excites the conversion of the sugar of milk into lactic acid. The lactic acid in its turn coagulates the caseum, which in the consolidation of its particles attracts the butter The caseum then ceases to act upon the sugar of milk, and consequently produces no more lactic acid.

But now, if the lactic acid already formed be saturated, the caseum will redissolve, and the phenomena will recommence in the same order. This is easily done by adding a due dose of bicarbonate of soda to the soured milk. In the course of 30 hours a fresh portion of lactic acid will be generated, and will have coagulated the milk again. We may also add some sugar of milk to the liquid, and to a certain extent convert it into lactic acid. Milk boiled, and kept from contact of air, will not coagulate, and remains fresh for many months. Animal membranes, modified by exposure to moist air for some time, form a true ferment for the lactic fermentation, and acidify solutions of sugar, dextrine, and gum, but the membranes must not be putrescent. Cane-sugar, starch-sugar, and sugar of milk, by assuming or losing a little water, acquire the constitution of lactic acid.

Viscous or Mucous Fermentation.—Every one is acquainted with this spontaneous modification of white wine and ale, which gives them a stringy or oily aspect, and is called in French *graisse,* or fat of wines, and in English the ropiness of beer. The viscous fermentation may be excited by boiling yeast with water, and dissolving sugar in the decoction, after it has been filtered. The syrup should have a specific gravity from 1·040 to 1·055, and be kept in a warm place. It soon assumes the consistence and aspect of a thick mucilage, like linseed tea, with the disengagement of a little carbonic acid and hydrogen, in the proportion of 2 or 3 of the former gas to 1 of the latter. A ferment of globular texture like that of yeast is formed, which is capable of producing viscous fermentation in any saccharine solution to which it is added, provided the temperature be suitable. The viscid matter being evaporated to dryness forms transparent plates, of a sub-nauseous taste, and soluble in water, but less easily than gum arabic. Its mucilage is, however, thicker than that of gum, and yields with nitric acid, oxalic acid, but no mucic acid. Four parts of sugar, treated as above described, furnish 2·84 of unchanged sugar, and 1·27 of the mucilage; from which it appears that water becomes fixed in the transformation. Muriatic, sulphuric, sulphurous acids, and alum, prevent the production of the viscous fermentation, by precipitating its ferment. It is probably the soluble portion of gluten which is the cause of this species of fermentation. It has been found, accordingly, that tannin, which precipitates the said glutinous ferment, completely stops the viscous fermentation, or *graisse,* of wines. It is owing to the tannin which the red wines derive from the grape-stalks, with which they are long in contact during fermentation, that they are preserved from this malady of the white wines. The gluten of must is of two kinds the one soluble in virtue of the alcohol and tartaric acid, and producing the viscous, the other insoluble, and producing the alcoholic fermentation. The art of the wine maker consists in precipitating the injurious ferment, without impeding the action of the beneficial one; an art of considerable delicacy with regard to sparkling wines.

Acid Fermentation has been fully discussed under acetic acid. It requires the presence of ready formed alcohol and air. The lactic fermentation, on the contrary, may take place with starchy or saccharine substances, without the intervention of alcohol or constant exposure to the atmosphere; and when once begun, it can go on without air. Acetification has a striking analogy with nitrification, as is shown by the necessity of a high temperature, and the utility of porous bodies for exposing the liquid on a great surface to the air.

Benzoic Fermentation is that which transforms the azotised neutral crystalline matter, existing in bitter almonds, which has no action upon the animal economy, into new and remarkable products, among others the hydrure of benzöile and hydrocyanic (prussic) acid, which together constitute the liquid, called oil, or essence, of bitter almonds, a compound possessed of volatility and poisonous qualities. The attentive study of this fermentation has revealed a great fact in vegetable physiology, the spontaneous production, by means of certain artifices, of certain volatile oils, not pre-existing in the plants, yet capable of being generated in the products of their decomposition. The volatile oil of bitter almonds constitutes in this respect a starting point, from which have proceeded the oil of mustard, the oil of spiræa, and which will likely lead to other discoveries of the same kind. See ALMOND and AMYGDALINE.

Sinapic Fermentation is that by which the oil of mustard is formed, and which takes place by the contact of water, under certain conditions, of too refined and scientific a nature for this practical work.

Pectic Fermentation.—Pectic acid may be obtained from the expressed juice of carrots, and it seems to be formed in the process of extraction by the reaction of albumine in the carrots upon a substance called pectine; a transformation analogous therefore with that which takes place in the formation of the essence of bitter almonds.

Gallic Fermentation.—Gallic acid does not exist ready formed in nut-galls, but is generated from their tannin when they are ground, made pasty with water, and exposed to the air. This conversion may be counteracted by the red oxide of mercury, alcohol, sulphuric, muriatic, and nitric acids, bromine, essence of turpentine, creosote, oxalic, acetic, and prussic acids. The tannin disappears in the sequel of the above metamorphosis.

Fatty Fermentation.—All fats are transformed by the action of an alkaline or other base into certain acids, the stearic, margaric, the oleic, ethalic, &c. When these acids are once formed, they can not by any means, hitherto known, be reconverted into the primitive fat. By the fixation of water in the acid and the base (called *glycerine*), a change is effected which can not be undone, because the glyceric base is incapable by itself to displace the water, once combined in the hydrated fat acid. The circumstances necessary to the fatty fermentation, are like those of other fermentations; namely, the co-operation of an albuminoid matter, along with water, and a temperature of from 60° to 86° F.; under these conditions, the matter becomes warm, and assumes speedily the character of rancidity; acid is generated, and the carbonate of soda can then form salts, while the fatty acid is liberated; a circumstance impossible when the fat was acted upon in the neutral state. This altered fat, treated with water, gives up to it *glyceric alcohol.*

Digestive Fermentation.—Digestion of food may be considered in its essential features as a peculiar fermentative process. The gastric juice is a genuine ferment. Tiedmann, Gmelin, and Prout, have shown that the gastric juice contains muriatic acid; and Eberli has made interesting experiments on the digestion of food out of the body, with water containing a few drops of the same acid. He observed that when this liquid contained none of the mucous secretion of the stomach, it did not dissolve the aliments put into it; but with a little of that mucus it acquired that property in an eminent degree. Even the mucus of the bladder had a like effect. Schwann and Vogel have produced this digestive principle in a pure state, called by them *pepsine*, as obtained most abundantly from the stomachs of swine. The glandular part of that viscus being separated from the serous, is cut into small pieces, and washed with cold distilled water. After digestion for 24 hours, that water is poured off, and fresh water is poured on. This operation is repeated for several days, till a putrid odor begins to be felt. The watery infusion thus obtained is precipitated by acetate of lead. This white flaky precipitate contains the *pepsine*, accompanied with much albumen. It is then washed, mixed with water, and subjected to a stream of sulphuretted hydrogen. The whole being now thrown on a filter, the coagulated albumen remains on the paper, along with the sul phuret of lead, while the pepsine liquor passes, associated with some acetic acid. If to this liquor a very small quantity of muriatic acid be added, it becomes capable of carrying on artificial digestion. Dry pepsine may be obtained by evaporating the above filtered liquor on a water bath, to a syrupy consistence, then adding to it absolute alcohol, which causes a bulky whitish precipitate. This dried in the air constitutes *pepsine*. It contains a minute quantity of acetic acid, which may be removed completely, by heating it some hours on the water bath. The white powder then obtained is soluble in water, and betrays the presence of no acid whatever. According to Vogel, this substance is composed of, carbon, 57·72; hydrogen, 5·67; azote, 21·09; oxygen, &c., 15.52 = 100. Vogel has proved the analogy between the action of pepsine and diastase by the following experiment:—

He dissolved two grains of pepsine in very weak muriatic acid, and put into this liquor heated to 81° F., small bits of boiled beef. In the course of a few hours the pieces became transparent on their edges, and not long after they were completely dissolved. He now added fresh morsels in succession, till those last put in remained unchanged. He found by analysis, that 1·98 grains of the pepsine were left, showing how minute a portion of this ferment was necessary to establish and effect digestion. In fact, we may infer that pepsine, like yeast, serves to accomplish digestion without any waste of its own substance whatever, or probably with its multiplication.

Rennet, with which milk is coagulated in making cheese, is somewhat of the same nature as pepsine. It has been called *chymosine*. But the simplest digesting liquor is the following:—

If 10,000 parts of water by weight be mixed with 6 parts of ordinary muriatic acid and a little rennet, a liquor is obtained capable of dissolving hard boiled white of egg, beef, gluten, &c., into a transparent jelly in a few hours.

Ammoniacal Fermentation.—Under this title may be described the conversion of urea into carbonate of ammonia under the influence of water, a ferment, and a favorable temperature. Urea is composed in atoms; reckoned

In volumes,	Carbon 4;	hydrogen 8;	azote 4;	oxygen 2;
which by fixing	—	4;	—	2;
give	4;	12;	4;	4:

which is 4 vol. of carbonic acid, and 8 of ammonia; equivalent to ordinary carbonate of ammonia. The fermentation of urea plays an important part in the reciprocal offices of vegetable and animal existence. By its conversion into carbonate of ammonia, urea becomes a food fit for plants; and by the intervention of the mucous ferment which urine contains, that conversion is effected. Thus the urea constitutes a neutral and innocuous substance while it remains in the bladder, but is changed into a volatile, alkaline, and acrid substance, when it is acted upon by the air. Yeast added to pure urea mixed with water, exercises no action on it in the course of several days; but when added to urine, it soon causes decomposition, with the formation of carbonate of ammonia, and disengagement of carbonic acid. The deposite on chamberpots ill-cleaned acts as a very powerful ferment on urine, causing the complete decomposition of fresh urine in one fifth of the time that would otherwise be requisite.

Nitrous Fermentation, as exhibited in the formation of nitric acid from the atmosphere, and consequent production of nitrates in certain soils, has been with much probability traced to the action of ammonia on oxygen, as the intermedium or ferment.

Caseous and putrid Fermentations.—Curd *is converted into cheese, when after being coagulated by rennet*, it is left to itself under certain conditions; and this constitutes the true distinctive character of caseum. In the production of cheese there is evidently the intervention of a peculiar ferment which is gradually formed, and the decomposition of the curd into new products.

For animal and vegetable matters to run into putrefaction, they must be in contact with air and water, at a certain temperature; viz., between the freezing and boiling points of water. The contact of a putrid substance acts as a ferment to fresh animal and vegetable matters. The reagents which counteract fermentation in general stop also putrefaction. In this process, myriads of microscopic animalcules make their appearance, and contribute to the destruction of the substances.

A dispute having taken place between some distillers in Ireland and officers of Excise, concerning the formation of alcohol in the vats or tuns by spontaneous fermentation, without the presence of yeast, the Commissioners of Excise thought fit to cause a series of experiments to be made upon the subject, and they were placed under my general superintendence. An experiment was made on the 6th of October, with the following mixture of corn:—

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2 Bushels of Barley, weighing - - - -	- 100lbs.	5 oz.
½ Bushel of Malt, - - - - -	- 21	7
½ Bushel of Oats - - - - -	- 20	12
Total, 3 Bushels, weighing - - -	- 142	8

The bruised corn was wetted with 26 gallons of water at the temperature of 160° F., and, after proper stirring, had 8 gallons more of water added to it at the average temperature of 194°. The mash was again well stirred, and at the end of 45 minutes the whole was covered up, having at that time a temperature of 138° F. Three hours afterward, 16 gallons of wash only were drawn off; being considerably less than should have been obtained, had the apparatus been constructed somewhat differently, as shall be presently pointed out. The gravity of that wash was 1·060, or, in the language of the distiller, 60°. After a delay of two hours more, twenty additional gallons of water at the temperature of 200° were introduced, when the mash was well stirred, and then covered up for two hours, at which period 23 gallons of fine worts of specific gravity 1·042 were drawn off. An hour afterward 12 gallons of water at 200° were added to the residual grains, and in an hour and a half 11 gallons of wort of the density 1·033 were obtained. Next morning the several worts were collected in a new mash tun. They consisted of 48 gallons at the temperature 80°, and of a specific gravity 2·0465 when reduced to 60°. Being set at 80°, fermentation soon commenced; in two days the specific gravity had fallen to 1·0317, in three days to 1·018, in four days to 1·013, and in five days to 1.012, the temperature having at last fallen to 78° F. The total attenuation was therefore 34½°, indicating the production of 3·31 gallons of proof spirit, while the produce by distillation in low wines was 3·22; and by rectification in spirits and feints it was 3·05. The next experiment was commenced on the 12th of October, upon a similar mixture of corn to the preceding. 48 gallons of worts of 1·043 specific gravity were set at 82° in the tun, which next day was attenuated to 1·0418, in two days to 1·0202, in three days to 1·0125, and in five days to 1·0105, constituting in the whole an attenuation of 32½°, which indicates the production of 3·12 gallons of proof spirits; while the produce of the first distillation was 2·93 in low wines, and that of the second in feints and spirits was 2·66. In these experiments the wash, when fermenting most actively, seemed to simmer and boil on the surface, with the emission of a hissing noise, and the copious evolution of carbonic acid gas. They prove beyond all doubt that much alcohol may be generated in grain worts without the addition of yeast, and that, also, at an early period; but the fermentation is never so active as with yeast, nor does it continue so long, or proceed to nearly the same degree of attenuation. I was never satisfied with the construction of the mash tun used in these experiments, and had accordingly suggested another form, by which the mash mixture could be maintained at the proper temperature during the mashing period. It is known to chemists that the diastase of malt is the true saccharifying ferment which converts the fecula, or starch of barley and other corn, into sugar; but it acts beneficially only between the temperatures of 145° and 168° F. When the temperature falls below the former number, saccharification languishes; and when it rises much above the latter, it is entirely checked. The new mash tun was made of sheet zinc, somewhat wider at bottom than top; it was placed in a wooden tun, so much larger as to leave an interstitial space between the two of a couple of inches at the sides and bottom. Through this space a current of water at 160° was made to circulate slowly during the mashing period. Three bushels of malt, weighing 125 lbs. 3 oz., were wetted with 30 gallons of water at 167°, and the mixture being well agitated, the mash was left covered up at a temperature of 140° during three hours, when 19 gallons of fine worts were drawn off at the specific gravity of 1·0902 or 90·2°. Twenty gallons more water at 167° were then added to the residuum, which afforded after two hours 28 gallons of wort at the gravity 1·036; 12 gallons of water at 167° were now poured on, which yielded after other two hours 15 gallons at the gravity 1·0185. Forty gallons of fine worts at 1·058 gravity and 68° temperature were collected in the evening of the same day, and let into the tun with 5 per cent. of yeast. The attenuation amounted in six days to 54°. The third wort of this brewing, amounting to 15 gallons, being very feeble, was mixed with 7 gallons of the first and second worts, put into a copper, and concentrated by boiling to 11 gallons, which had a gravity 1·058 at 60° F. They were separately fermented with 5 per cent. of yeast, and suffered an attenuation of 48½°. The produce of spirit from both indicated by the attenuation was 5·36 gallons; the produce in low wines was actually 5·52, and that in spirits and feints was 5·33, being a perfect accordance with the Excise tables.

The next experiments were made with a view of determining at what elevation of temperature the activity or efficiency of yeast would be paralysed, and how far the attenuation of worts could be pushed within six hours, which is the time limited by law for worts to be collected into the tun, from the time of beginning to run from the coolers. When worts of the gravity 1·0898 were set at 96° Fahr., with 5 per cent. of yeast, they attenuated 26·9° in 6 hours; worts of 1·0535 gravity set at 110° with 5 per cent. of yeast, attenuated 16° in about 5 hours; but when worts of 1·0533 were set, as above, at 120°, they neither fermented then, nor when allowed to cool; showing that the activity of the yeast was destroyed. When fresh yeast was now added to the last portion of worts, the attenuation became 5·8 in 2 hours, and 28·4° in 3 days; showing that the saccharine matter of the worts still retained its fermentative faculty. Malt worts, being brewed as above specified, were set in the tun, one portion at a temperature of 70°, with a gravity of 1·0939, and 5 per cent. of yeast, which attenuated 66° in 3 days; other two portions of the same gravity were set at 120° with about 10 per cent. of yeast, which underwent no fermentative change or attenuation in 6 hours, all the yeast having fallen to the bottom of the tuns. When these two samples of worts were allowed, however, to cool to from 74° to 72°, fermentation commenced, and produced in two days an attenuation of about 79°. It would appear, from these last two experiments, that yeast to the amount of 5 per cent. is so powerfully affected by strong worts heated to 120° as to have its fermentative energy destroyed; but that when yeast is added to the amount of 10 per cent., the 5 parts of excess are not permanently decomposed, but have their activity merely suspended till the saccharine liquid falls to a temperature compatible with fermentation. Yeast, according to my observations, when viewed in a good acromatic microscope, consists altogether of translucent spherical and spheroidal particles, each of about the 6000th part of an inch in diameter. When the beer in which they float is washed away with a little water, they are seen to be colorless; their yellowish tint, when they are examined directly from the fermenting square or round of a porter brewery, being due to the infusion of the brown malt. The yeast of a square newly set seems to consist of particles smaller than those of older yeast, but the difference of size is not considerable. The researches of Schulze, Cagniard de la Tour, and Schwann, appear to show, that the vinous fermentation, and the putrefaction of animal matters, processes which have been hitherto considered as belonging entirely to the domain of chemical affinity—are essentially the results of an organic development of living beings. This position seems to be established by the following experiments: 1. A matrass or flask containing a few bits of flesh, being filled up to one third of its capacity with water, was closed with a cork, into which two slender glass tubes were cemented air-tight. Both of these tubes were passed externally through a metallic bath, kept constantly melted, at a temperature approaching to that of boiling mercury. The end of one of the tubes, on emerging from the bath, was placed in communication with a gasometer. The contents of the matrass were now made to boil briskly, so that the air contained in it and the glass tubes was expelled. The matrass being then allowed to cool, a current of atmospherical air was made constantly to pass through it from the gasometer, while the metallic bath was kept constantly hot enough to decompose the living particles in the air. In these experiments, which were many times repeated, no infusoria or fungi appeared, no putrefaction took place, the flesh underwent no change, and the liquor remained as clear as it was immediately after being boiled. As it was found very troublesome to maintain the metallic bath at the melting pitch, the following modification of the apparatus was adopted in the subsequent researches: A flask of three ounces capacity, being one fourth filled with water and flesh, was closed with a tight cork, secured in its place by wire. Two glass tubes were passed through the cork; the one of them was bent down, and dipped at its end into a small capsule containing quicksilver, covered with a layer of oil; the other was bent on leaving the cork, first into a horizontal direction, and downward for an inch and a half, afterward into a pair of spiral turns, then upward, lastly horizontal, whence it was drawn out to a point. The pores of the cork having been filled with caoutchouc varnish, the contents of the flask were boiled till steam issued copiously through both of the glass tubes, and the quicksilver and oil became as hot as boiling water. In order that no living particles could be generated in the water condensed beneath the oil, a few fragments of corrosive sublimate were laid upon the quicksilver. During the boiling, the flame of a spirit lamp was drawn up over the spiral part of the second glass tube, by means of a glass chimney placed over it, so as to soften the glass, while the further part of the tube was heated by another spirit lamp, to prevent its getting cracked by the condensation of the steam. After the ebullition had been kept up a quarter of an hour, the flask was allowed to cool, and get filled with air through the hot spiral of the second tube. When the contents were quite cold, the end of this tube was hermetically sealed, the part of it between the point and the spiral was heated strongly with the flames, and the lamps were then withdrawn. The matrass contained now nothing but boiled flesh and gently ignited air. The air was renewed occasionally through the second tube, its spiral part being first strongly heated, its point then broken off, and connected with a gasometer, which caused the air to pass onward slowly, and escape at the end of the first tube immersed in the quicksilver. The end of the second tube was again hermetically closed, while the part interjacent between it and the spiral was exposed to the spirit flame. By means of these precautions, decoctions of flesh were preserved, during a period of six weeks, in a temperature of from 14° to 20° R. (63½° to 77° F.), without any appearance of putrefaction, infusoria, or mouldiness: on opening the vessel, however, the contents fermented in a few days, as if they had been boiled in the ordinary manner. In conducting such researches, the greatest pains must be taken to render the cork and junctions of the glass tubes perfectly air-tight. The following more convenient modification of the experiment, but one equally successful and demonstrative, was arranged by F. Schulze. The glass tubes connected with the flask were furnished each with a bulb at a little distance from the cork; into one of which globes caustic alkaline ley being put, and into the other strong sulphuric acid, air was slowly sucked through the extremity of the one tube, while it entered at the other, so as to renew the atmosphere over the decoction of flesh in the flask. In another set of experiments, four flasks being filled with a solution of cane-sugar containing some beer-yeast, were corked and plunged in boiling water till they acquired its temperature. They were then taken out, inverted in a mercurial bath, uncorked, and allowed to cool in that position. From one third to one fourth of their volume of atmospherical air was now introduced into each of the flasks; into two of them through slender glass tubes kept red hot at a certain point, into the other two through glass tubes not heated. By analysis it was found that the air thus heated contained only 19·4 per cent. of oxygen, instead of 20·8; but, to compensate for this deficiency, a little more air was admitted into the two flasks connected with the heated tubes than into the two others. The flasks were now corked and placed in an inverted position, in a temperature of from 10° to 14° R. (54½° to 63½° F.). After a period of from four to six weeks, it was found that fermentation had taken place in both of the flasks which contained the non-ignited air—for, in loosening the corks, some of the contents were projected with force—but, in the other two flasks, there was no appearance of fermentation, either then, or in double the time. As the extract of nux vomica is known to be a poison to *infusoria* (animalcules), but not to vegetating mould, while arsenic is a poison to both, by these tests it was proved that the living particles instrumental to fermentation belonged to the order of plants of the confervoid family. Beer yeast, according to Schwann, consists entirely of microscopic fungi, in the shape of small oval grains of a yellowish white color, arranged in rows oblique to each other. Fresh grapes must contain none of them; but after being exposed to the air at 20° R., for 36 hours, similar grains become visible in the microscope, and may be observed to grow larger in the course of an hour, or even in half that time. A few hours after these plants are first perceived, gas begins to be disengaged. They multiply greatly in the course of fermentation, and at its conclusion subside to the bottom of the beer in the shape of a yellow white powder.

FERRIC ACID. This new compound having been prescribes as a source of supplying oxygen to persons confined in diving-bells and in mines, by M. Payerne, in a patent recently granted to him, merits notice in a practical work. M. Fremy is the discoverer of this new acid, which he obtains in the state of ferrate of potash, by projecting 10 parts of dry nitre in powder upon 5 parts of iron filings, ignited in a crucible; when a reddish mass, containing much ferrate of potash, is formed. The preparation succeeds best when a large crucible, capable of holding about a pint of water, is heated so strongly that the bottom and a couple of inches above it, appear faintly, but distinctly red, in which state the heat is just adequate to effect due deflagration without decomposition. An intimate mixture of about 200 grains of *dried* nitre with about one half its weight of the finest iron filings, is to be thrown at once upon the side of the crucible. The mixture will soon swell and deflagrate. The crucible being taken from the fire, and the ignited mass being cooled, is to be taken out with an iron spoon, pounded, immediately put into a bottle, and secluded from the air, in which it would speedily attract moisture, and be decomposed. It is resolved by the action of water, especially with heat, into oxygen gas, peroxide, and nitrate of iron.

Mr. J. D. Smith prepares the ferrate of potash by exposing to a full red heat a mixture of finely powdered peroxide of iron with four times its weight of dry nitre. It has an amethyst hue, but so deep as to appear black, except at the edges. Oxygen is rapidly evolved by the action of the sulphuric or nitric acid upon its solution. He considers the atom of iron to exist in this compound, associated with 3 atoms of oxygen, or double the proportion of that in the red oxide. Hence 52 grains of pure ferric acid should give off 12 grains of oxygen, equal to about 35 cubic inches; but how much of the ferrate of potash may be requisite to produce a like quantity of oxygen cannot be stated, from the uncertainty of the operation by which it is produced.

FERRIC-CYANIDE OF POTASSIUM, or *Red Prussiate of Potash.* This beautiful and useful salt, discovered by L. Gmelin, is prepared by passing chlorine gas through a weak solution of the prussiate of potash (ferro-cyanide of potassium) till it ceases to affect solution of red sulphate of iron, taking care to agitate the liquid all the while, and not to add an excess of chlorine. On looking through the weak solution to the flame of a candle, one may see the period of change from the greenish to the red hue, which indicates the completion of the process. The liquor being filtered and evaporated in a dish with upright sides, will eventually afford crystalline needles, possessed of an almost metallic lustre, and a yellow color, inclining to red. These being dissolved and recrystallized, will become extremely beautiful. This salt is composed of 33·68 parts of potassium, 16·48 of iron, and 47·84 of cyanogen. It is therefore a dry salt. It dissolves in 38 parts of cold water, and as it forms then the most delicate test of the protoxide of iron, is very useful in *Clorometry*.—See Alkalimetry.

The solution of this salt affords the following colored precipitates with the solutions of the respective metals :—

Titanium - - - -	Brownish yellow.
Uranium - - - -	Reddish brown.
Manganese - - - -	Brownish gray.
Cobalt - - - -	Deep reddish brown.
Nickel - - - -	Yellowish brown.
Copper - - - -	Dirty yellowish brown.
Silver - - - -	Orange yellow.
Mercury - - - -	Yellow, with both the protoxide and peroxide salts.
Tin - - - -	White.
Zinc - - -	Orange Yellow.
Bismuth - - -	Yellowish brown.
Lead - - -	No precip.
Iron protoxide - - - -	Blue.
—— peroxide - - - -	No precip.

The ferric-cyanide of potassium has been introduced into dyeing and calico-printing.

In case an excess of chlorine has been used in preparing the above salt, Posselt recommends to add to its solution, when near the crystalline point, a few drops of potash lye, in order to decompose a green substance that is present, which takes place with the precipitation of a little peroxide of iron.

FERROCYANATE, or, more correctly, FERROCYANIDE. (*Ferrocyanure*, Fr.; *Eisencyanid*, Germ.) Several compounds of cyanogen and metals possess the property of uniting together into double cyanides; of which there are none so remarkable in this respect, as the protocyanide of iron. This appears to be capable of combining with several simple cyanides, such as that of potassium, sodium, barium, strontium, calcium, and ammonium. The only one of these double cyanides of any importance in manufactures is the first, which is described under its commercial name, Prussiate of Potash.

FERROPRUSSIATES; another name for Ferrocyanides.

FIBRE, VEGETABLE, called also Lignine (*Ligneux*, Fr.; *Pflanzen-faserstoff*, Germ.), is the most abundant and general ingredient of plants, existing in all their parts, the root, the leaves, the stem, the flowers, and the fruit; amounting in the compact wood to 97 or 98 per cent. It is obtained in a pure state by treating saw-dust successively with hot alcohol, water, dilute muriatic acid, and weak potash ley, which dissolve, first, the resinous; second, the extractive and saline matters; third, the carbonate and phosphate of lime; and, lastly, any residuary substances. Ligneous fibres, such as saw-dust, powdered barks, straw, hemp, flax, linen, and cotton cloth, are convertible by the action of strong sulphuric acid into a gummy substance analogous to *dextrine*, and a sugar resembling that of the grape.

If we put into a glass mortar 24 parts, by weight, of dry old cordage, chopped small, and sprinkle over it 34 parts of sulphuric acid, by degrees, so as to avoid heating the mixture, while we constantly stir it; and if, in a quarter of an hour, we triturate the mass with a glass pestle, the fibres will disappear without the disengagement of gas. A tenacious mucilage will be produced, almost entirely soluble in water. The gum being thus formed, may be separated from the acid by dilution with water, and addition of the requisite quantity of chalk; then straining the saturated liquid through linen cloth, concentrating it by evaporation, throwing down any remaining lime by oxalic acid, filtering anew, and mixing the mucilage with alcohol in great excess, which will take up the free acid, and throw down the gum. From 24 parts of hemp fibres thus treated, fully 24 parts of a gummy mass may be obtained, containing, however, probably some water.

When, instead of saturating the diluted acid paste with chalk, we boil it for 10 hours, the gummy matter disappears, and is replaced by sugar, which may be purified without any difficulty, by saturation with chalk, filtration, and evaporation to the consistence of sirup. In 24 hours crystallization begins, and, in 2 or 3 days, a concrete mass of grape sugar is formed; which needs merely to be pressed strongly between old linen cloths doubled, and then crystallized a second time. If this sirup be treated with bone black, a brilliant white sugar will be procured. 20 parts of linen rags yield 23 of good sugar. *Braconnot.* Guerin got 87½ of dry sugar from 100 parts of rags, treated with 250 of sulphuric acid. See WOOD.

FIBRINE (Eng. and Fr.; *Thierischer Faserstoff*, Germ.) constitutes the principal part of animal muscle; it exists in the chyle, the blood, and may be regarded as the most abundant constituent of animal bodies. It may be obtained in a pure state by agitating or beating new drawn blood with a bundle of twigs, when it will attach itself to them in long reddish filaments, which may be deprived of color by working them with the hands under a streamlet of cold water, and afterwards freed from any adhering grease by digestion in alcohol or ether.

Fibrine, thus obtained, is solid, white, flexible, slightly elastic, insipid, inodorous, denser than water, but containing four fifths of its weight of it, and without action on litmus. When dried, it becomes semi-transparent, yellowish, stiff, and brittle: water restores its softness and flexibility. 100 parts of fibrine consist of 53·36 carbon, 19·68 oxygen, 7·02 hydrogen, and 19·31 azote. As the basis of flesh, it is a very nutritious substance, and is essential to the sustenance of carnivorous animals.

FILE (*Lime*, Fr.; *Feile*, Germ.) is a well known steel instrument, having teeth upon the surface for cutting and abrading metal, ivory, wood, &c.

When the teeth of these instruments are formed by a straight sharp-edged chisel, extending across the surface, they are properly called files; but when by a sharp-pointed tool, in the form of a triangular pyramid, they are termed rasps. The former are used for all the metals, as well as ivory, bone, horn, and wood; the latter for wood and horn.

Files are divided into two varieties, from the form of their teeth. When the teeth are a series of sharp edges, raised by the flat chisel, appearing like parallel furrows, either at right angles to the length of the file, or in an oblique direction, they are termed *single cut.* But when these teeth are crossed by a second series of similar teeth, they are said to be *double cut.* The first are fitted for brass and copper, and are found to answer better when the teeth run in an oblique direction. The latter are suited for the harder metals, such as cast and wrought iron and steel. Such teeth present sharp angles to the substance, which penetrate it, while single cut files would slip over the surface of these metals. The double cut file is less fit for filing brass and copper, because its teeth would be very liable to become clogged with the filings.

Files are also called by different names according to their various degrees of fineness. Those of extreme roughness are called rough; the next to this is the bastard cut; the third is the second cut; the fourth, the smooth; and the finest of all, the dead smooth. The very heavy square files used for heavy smith-work, are sometimes a little coarser than the rough; they are known by the name of rubbers.

Files are also distinguished from their shape, as flat, half-round, three-square, four-square, and round. The first are sometimes of uniform breadth and thickness throughout, and sometimes tapering. The cross section is a parallelogram. The half-round is generally tapering, one side being flat, and the other rounded. The cross section is a segment of a circle, varying a little for different purposes, but seldom equal to a semi-circle. The three-square generally consists of three equal sides, being equilateral prisms, mostly tapering; those which are not tapering are used for sharpening the teeth of saws. The four-square has four equal sides, the section being a square. These files are generally thickest in the middle, as is the case with the smith's rubber. In the round file, the section is a circle, and the file generally conical.

The heavier and coarser kinds of files are made from the inferior marks of blistered steel. Those made from the Russian iron, known by the name of old sable, called from its mark CCND, are excellent. The steel made from the best Swedish iron, called hoop L or Dannemora, makes the finest Lancashire files, for watch and clock makers; a manufacture for which the house of Stubbs in Warrington is celebrated.

The steel intended for files is more highly converted than for other purposes, to give them proper hardness. It should however be recollected, that if the hardness be not accompanied with a certain degree of tenacity, the teeth of the file break, and do but little service.

Small files are mostly made of cast steel, which would be the best for all others, if it were not for its higher price. It is much harder than the blistered steel, and from having been in the fluid state, is entirely free from those seams and loose parts so common to blistered steel, which is no sounder than as it comes from the iron forge before conversion.

The smith's rubbers are generally forged in the common smith's forge, from the converted bars, which are, for convenience, made square in the iron before they come into this country. The files of lesser size are made from bars or rods, drawn down from the blistered bars, and the cast ingots, and known by the name of tilted steel.

The file-maker's forge consists of large bellows, with coke as fuel. The anvil-block, particularly at Sheffield, is one large mass of mill stone girt. The anvil is of considerable size, set into and wedged fast into the stone; and has a projection at one end, with a hole to contain a sharp-edged tool for cutting the files from the rods. It also contains a deep groove for containing dies or bosses, for giving particular forms to the files.

The flat and square files are formed entirely by the hammer. One man holds the hot bar, and strikes with a small hammer. Another stands before the anvil with a two-handed hammer. The latter is generally very heavy, with a broad face for the large files. They both strike with such truth as to make the surface smooth and flat, without what is called hand-hammering. This arises from their great experience in the same kind of work. The expedition arising from the same cause is not less remarkable.

The half-round files are made in a boss fastened into the groove above mentioned. The steel being drawn out, is laid upon the rounded recess, and hammered till it fills the die.

The three-sided files are formed similarly in a boss, the recess of which consists of two sides, with the angle downwards. The steel is first drawn out square, and then placed in a boss with an angle downwards, so that the hammer forms one side, and the boss two. The round files are formed by a swage similar to those used by common smiths, but a little conical.

The file-cutter requires an anvil of a size greater or less, proportioned to the size of his files, with a face as even and flat as possible. The hammers weigh from one to five or six pounds. The chisels are a little broader than the file, sharpened to an angle of about 20 degrees. The length is just sufficient for them to be held fast between the finger and thumb, and so strong as not to bend with the strokes of the hammer, the intensity of which may be best conceived by the depth of the impression. The anvil is placed in the face of a strong wooden post, to which a wooden seat is attached, at a small distance below the level of the anvil's face. The file is first laid upon the bare anvil, one end projecting over the front, and the other over the back edge of the same. A leather strap now goes over each end of the file, and passes down upon each side of the block to the workman's feet, which, being put into the strap on each side, like a stirrup, holds the file firmly upon the anvil as it is cut. While the point of the file is cutting, the strap passes over one part of the file only, the point resting upon the anvil, and the tang upon a prop on the other side of the strap. When one side of the file is single cut, a fine file is run slightly over the teeth, to take away the roughness; when they are to be double cut, another set of teeth is cut, crossing the former nearly at right angles. The file is now finished upon one side, and it is evident that the cut side cannot be laid upon the bare anvil to cut the other. A flat piece of an alloy of lead and tin is interposed between the toothed surface and the anvil, while the other side is cut, which completely preserves the side already formed. Similar pieces of lead and tin, with angular and rounded grooves, are used for cutting triangular and half-round files.

Rasps are cut precisely in the same way, by using a triangular punch instead of a flat chisel. The great art in cutting a rasp is to place every new tooth as much as possible opposite to a vacancy.

Many abortive attempts have been made to cut the teeth of files by machinery. The following plan, for which a patent was obtained by Mr. William Shilton, of Birmingham, in April, 1833, is replete with ingenious mechanical resources, and deserves to succeed.

The blanks of steel for making the files and rasps, are held in a pair of clamps in connexion with a slide, and are moved forward at intervals under the head of the tilt hammer which carries the tool; the distance which the blank is to be advanced at every movement being dependant upon the required fineness or coarseness of the cut of the file, which movement is effected and regulated by a rack and pinion, actuated by a pall and ratchet wheel, or the movement may be produced by any other convenient means.

When the machine is employed for cutting or indenting the teeth of rasps, the cutting tool being pointed and only producing one tooth at a blow, the tilt hammer carrying the tool must be made to traverse at intervals across the width of the blank piece of steel from one edge to the other and back again; the blank being advanced in length only when the hammer has produced the last cut or tooth toward either edge of the rasp.

In order to render this invention better understood, two views of the apparatus for producing the cross-cut or teeth of the files are given.

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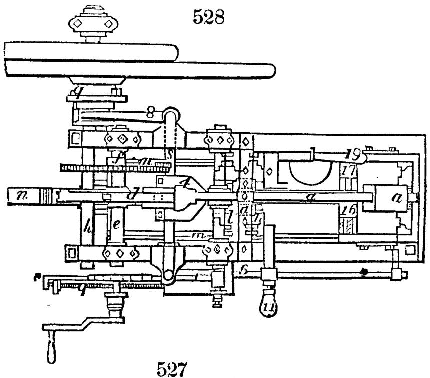

527

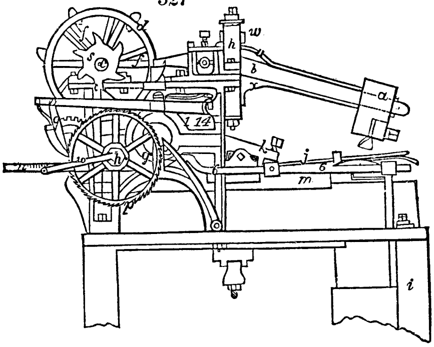

Fig. 527 is an elevation of the upper part of the file-cutting machine, as seen on one side; *fig.* 528 is a plan or horizontal view, as the machine appears on the top.

a, is the head of the tilt hammer placed in the end of the lever *b*, which is mounted on an axle *c*, turning in proper bearings in the frame work of the machine; *d*, is the tilt wheel mounted on another axle *s*, also turning in bearings on the frame work of the machine, and having any required number of projections or tappets upon it for depressing the tail or shorter end of the hammer or tilt lever *b*.

The tilt wheel *d*, receives its rotatory motion from the toothed wheel *f*, mounted upon the same axle, and it takes into gear with a pinion *g*, upon the main shaft *h*, which is actuated by a band passed from any first' mover to the rigger on its end, or in any other convenient manner. The bed upon which the blank piece of steel bears is marked *i*. This bed is firmly supported upon masonry placed upon proper sleepers; *j*, is one of the blank pieces of steel under operation, and is shown secured in the pair of jaws or holding clamps *k*, mounted on centre pins in the slide *l*, *fig.* 528; which slide is held down by a spring and slide beneath, and is moved backwards and forwards in the machine upon the (v) edges *m*, *m*, of the frame, by means of the rack *n*, and its pinion; the latter being mounted upon the axle of the ratchet wheel *p*, and which ratchet wheel is made to turn at intervals by means of the pall *q*, upon the end of the lever *r*, *fig.* 528. This lever is depressed, after every cut has been effected upon the blank by means of the teeth or tappets of the wheel *s*, coming in contact with the inclined plane *t*, upon the lever *r*. The tappet wheel *s*, is mounted upon the end of the axle *e*, of the tilt wheel, and consequently revolves with it, and by depressing the lever *r*, every time that a tooth passes the inclined plane *t*, the click *q*, is made to drive the ratchet wheel *p*, and thereby the advancing movement of the blank is effected after each blow of the tilt hammer.

There is a strong spring *u*, attached to the upper side of the tilt hammer, its end being confined under an adjustable inclined plane *v*, mounted in the frame *w*, which inclined plane can be raised or lowered by its adjusting screws as required, to produce more or less tension of the spring.

A similar spring is placed on the under side of the tilt hammer, to raise and sustain the cutter or tool clear of the bed after every blow, and in conjunction with safety holders or catchers, to counteract any vibration or tendency the spring *u* may have to cause the hammer to reiterate the blow.

The end of the lower spring acts on an inclined plane, mounted in the frame *w*, which has an adjusting screw similar to *v*, to regulate the tension of the spring.

In case the under spring should raise, that is, return the hammer, with sufficient force or velocity to cause the top spring *u*, to reiterate the blow, the ends of the safety holders or catchers are made to move under and catch the tail of the lever *b*, immediately on its being raised by the under springs, which is effected by the following means:—The holders are mounted upon a plate or carriage 1, *fig.* 527, which turns upon a small pin or axle mounted in the ears of a cross bar; the upper ends of the holders are kept inclined towards the tail of the tilt hammer by means of a spring fixed to the cross bar, and which acts upon one end of the plate or carriage 1.

In order that the holders may be removed out of the way of the tail of the hammer *b*, when the tilt wheel is about to effect a blow, the tooth of the tilt wheel which last acted upon the hammer comes in contact with an inclined plane fixed on the plate or carriage 1, and by depressing that end of the plate, causes the upper ends of the holders to be withdrawn from under the tail of the hammer *b*. The tilt wheel continuing to revolve, the next tooth advances, and depresses the tail of the hammer, but before it leaves the tail of the hammer, the tooth last in operation will have quitted the inclined plane and allowed the spring to return the holders into their former position. After the tooth has escaped from the tail of *b*, the hammer will immediately descend and effect the blow or cut on the blank, and as the tail of the hammer rises, it will come in contact with the inclined planes at the upper ends of the holders, and force them backwards; and as soon as the tail of the hammer has passed the top of the holders, the spring will immediately force the holders forward under the tail of the hammer, and prevent the hammer rising again until the next tooth of the tilt wheel is about to depress the end of the hammer, when the same movements of the parts will be repeated, and the machine will continue in operation until a sufficient length of the blank of steel (progressively advanced under the hammer) has been operated upon, when it will be thrown out of gear by the following means:—

Upon the sliding bar 6 there is placed an adjustable stop, against which the foremost end of the slide *l l*, *fig.* 528, comes in contact as it is moved forward by the rack *n*, and its pinion. The sliding bar 6 is connected at its left end to the bent lever 8, the other end of this lever being formed into a forked arm, which embraces a clutch upon the main shaft, and as the slide *l* continues to advance, it will come in contact with a stop; and when it has brought a sufficient length of the blank pieces of steel under the operation of the cutting tool, the slide *l*, in its progress, will have moved that stop and the bar 6 forward, and that bar, by means of the bent lever 8, will withdraw the clutch on the main shaft, from locking into the boss of the fly-wheel, and consequently stop the further progress of the machine; the rigger and fly-wheel turning loosely upon the main shaft.

The cut file can now be removed from out of the clamps, and reversed to cut the other side, or another blank piece put in its place; and after throwing back the pall *q* of the ratchet wheel *p*, the slide *l*, and with it the fresh blank may be moved back into the machine by turning the winch handle, on the axle of the ratchet wheel *p*, the reverse way, which will turn the pinion backwards, and draw back the rack *n*, without affecting any other parts of the machine; and on moving back the bar 6, by the handle 11, placed on the stop, the clutches will be thrown into gear again, and the machine proceed to cut the next blank.

When the blanks have been thus cut on one side, and are reversed in the machine to form the teeth upon the other side, there should be a piece of lead placed between the blank and the bed to protect the fresh cut teeth.

It will be seen that the position of the stop upon the bar 6 will determine the length or extent of the blank piece of steel which shall be cut or operated upon; and in order that the progressive movement of the blanks under the cutting tool may be made to suit different degrees of fineness or coarseness of the teeth (that is, the distance between the cuts), there is an adjusting screw upon the lever *r*, the head of which screw stops against the under side of an ear projecting from the frame-work, and thereby determines the extent of the motion of the lever *r*, when depressed by the tappets of the wheel *s*, acting upon the inclined plane *t*, consequently determining the number of teeth the ratchet wheel *p* shall be moved round by the pall *q*; and hence the extent of motion communicated by the rack and pinion to the slide *l*, and the blank *j*, which regulates the distance that the teeth of the file are apart, and the lever *r* is forced upwards by a spring pressing against its under side.

It will be perceived that the velocity of the descent of the hammer, and consequently the force of the blow, may be regulated by raising or lowering the inclined plane *v* of the spring *u*; and in order to accommodate the bed upon which the blanks rest to the different inclinations they may be placed at, that part of the bed is formed of a semi-globular piece of hardened steel, which fits loosely into a similar concavity in the bed *r*, and is therefore capable of adjusting itself so that the blanks shall be properly presented to the cutting tool, and receive the blow or cut in an equal and even manner; or the piece of steel may be of a conical shape, and fit loosely in a similar shaped concavity.

There are guides, 16, placed on the top of the bed *i*, for the purpose of keeping the blanks in their proper position towards the cutting tool, and these can be regulated to suit blanks of any width, by turning the right and left handed screw 17. There is also another adjustable stop on the jaws or clamps *k*, which serves as a guide when placing the blanks within the jaws; and 19 is a handle or lever for raising the clamps when required, which has a weight suspended from it for the purpose of keeping down the blanks with sufficient pressure upon the bed.

The cutting tool in the face of the hammer, can be placed at any required angle or inclination with the blank, it being secured in the head of the hammer by clamps and screws. In cutting fine files a screw is employed in preference to the rack and pinion, for advancing the slide *l*, and the blank piece of steel in the machine.

Hardening of files.—This is the last and most important part of file making. Whatever may be the quality of the steel, or however excellent the workmanship, if it is not well hardened all the labor is lost.

Three things are strictly to be observed in hardening; first, to prepare the file on the surface, so as to prevent it from being oxydated by the atmosphere when the file is red hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough that the file would, in a little time, become clogged with the substance it had to work. Secondly, the heat ought to be very uniformly red throughout, and the water in which it is quenched, fresh and cold, for the purpose of giving it the proper degree of hardness. Lastly, the manner of immersion is of great importance, to prevent the files from warping, which in long thin files is very difficult.

The first object is accomplished by laying a substance upon the file, which, when it fuses, forms, as it were, a varnish upon the surface, defending the metal from the action of the oxygen of the air. Formerly the process consisted in first coating the surface of the file with ale grounds, and then covering it over with pulverized common salt (muriate of soda). After this coating became dry, the files were heated red hot, and hardened; after this, the surface was lightly brushed over with the dust of cokes, when it appeared white and metallic, as if it had not been heated. This process has lately been improved, at least so far as relates to the economy of the salt, which, from the quantity used, and the increased thickness, had become a serious object. Those who use the improved method are now consuming about one fourth the quantity of salt used in the old method. The process consists in dissolving the salt in water to saturation, which is about three pounds to the gallon, and stiffening it with ale grounds, or with the cheapest kind of flour, such as that of beans, to about the consistence of thick cream. The files require to be dipped only into this substance, and immediately heated and hardened. The grounds or the flour are of no other use than to give the mass consistence, and by that means to allow a larger quantity of salt to be laid upon the surface. In this method the salt forms immediately a firm coating. As soon as the water is evaporated, the whole of it becomes fused upon the file. In the old method the dry salt was so loosely attached to the file, that the greatest part of it was rubbed off into the fire, and was sublimed up the chimney, without producing any effect.

The carbonaceous matter of the ale grounds is supposed to have some effect in giving hardness to the file, by combining with the steel, and rendering it more highly carbonated. It will be found, however, upon experiment, that vegetable carbon does not combine with iron, with sufficient facility to produce any effect, in the short space of time a file is heating for the purpose of hardening. Some file makers are in the habit of using the coal of burnt leather, which doubtless produces some effect; but the carbon is generally so ill prepared for the purpose, and the time of its operation so short, as to render the result inconsiderable. Animal carbon, when properly prepared and mixed with the above hardening composition, is capable of giving hardness to the surface even of an iron file.

This carbonaceous matter may be readily obtained from any of the soft parts of animals, or from blood. For this purpose, however, the refuse of shoemakers and curriers is the most convenient. After the volatile parts have been distilled over, from an iron still, a bright shining coal is left behind, which, when reduced to powder, is fit to mix with the salt. Let about equal arts, by bulk, of this powder, and muriate of soda be ground together, and brought to the consistence of cream, by the addition of water. Or mix the powdered carbon with a saturated solution of the salt, till it become of the above consistence. Files which are intended to be very hard should be covered with this composition previous to hardening. All files intended to file iron or steel, particularly saw files, should be hardened with the aid of this mixture, in preference to that with the flour or grounds. Indeed, it is probable that the carbonaceous powder might be used by itself, in point of economy, since the ammonia or hartshorn, obtained by distillation, would be of such value as to render the coal of no expense. By means of this method the files made of iron, which, in itself, is unsusceptible of hardening, acquire a superficial hardness sufficient for any file whatever. Such files may, at the same time, be bent into any form; and, in consequence, are particularly useful for sculptors and die-sinkers.

The next point to be considered is the best method of heating the file for hardening. For this purpose a fire, similar to the common smith's fire, is generally employed. The file is held in a pair of tongs by the tang, and introduced into the fire, consisting of very small cokes, pushing it more or less into the fire for the purpose of heating it regularly. It must frequently be withdrawn with the view of observing that it is not too hot in any part. When it is uniformly heated, from the tang to the point, of a cherry red color, it is fit to quench in the water. At present an oven formed of fire-bricks is used for the larger files, into which the blast of the bellows is directed, being open at one end, for the purpose of introducing the files and the fuel. Near to the top of the oven are placed two cross bars, on which a few files are placed, to be partially heating. In the hardening of heavy files this contrivance affords a considerable saving, in point of time, while it permits them also to be more uniformly and thoroughly heated.

After the file is properly heated for the purpose of hardening, in order to produce the greatest possible hardness, it should be cooled as soon as possible. The most common method of effecting this is by quenching it in the coldest water. Some file-makers have been in the habit of putting different substances in their water, with a view to increase its hardening property. The addition of sulphuric acid to the water was long held a great secret in the hardening of saw files. After all, however, it will be found that clear spring water, free from animal and vegetable matter, and as cold as possible, is the best calculated for hardening files of every description.

In quenching the files in water, some caution must be observed. All files, except the half-round, should be immersed perpendicularly, as quickly as possible, so that the upper part shall not cool. This management prevents the file from warping. The half-round file must be quenched in the same steady manner; but, at the same time that it is kept perpendicular to the surface of the water, it must be moved a little horizontally, in the direction of the round side, otherwise it will become crooked backwards.

After the files are hardened, they are brushed over with water and powdered cokes, when the surface becomes perfectly clean and metallic. They ought also to be washed well in two or three clean waters, for the purpose of carrying off all the salt, which, if allowed to remain, will be liable to rust the file. They should moreover be dipped into lime-water, and rapidly dried before the fire, after being oiled with olive oil, containing a little oil of turpentine, while still warm. They are then finished.

FILLIGREE (*Filigrane*, Fr.; *Filigran*, or *Feine Drahtgeflecht*, Germ.) is, as the last term justly expresses it, intertwisted fine wire, used for ornamenting gold and silver trinkets. The wire is seldom drawn round, but generally flat or angular, and soldered by gold or silver solder with borax and the blowpipe. The Italian word, *filigrana*, is compounded of *filum* and *granum*, or granular net-work; because the Italians, who first introduced this style of work, placed small beads upon it.

FILTRATION (Eng. and Fr.; *Filtriren*, Germ.) is a process, purely mechanical, for separating a liquid from the undissolved particles floating in it, which liquid may be either the useful part, as in vegetable infusions, or of no use, as the washings of mineral precipitates. The filtering substance may consist of any porous matter in a solid, foliated, or pulverulent form; as porous earthenware, unsized paper, cloth of many kinds, or sand. The white blotting paper sold by the stationers, answers extremely well for filters in chemical experiments, provided it be previously washed with dilute muriatic acid, to remove some lime and iron that are generally present in it. Filter papers are first cut square, and then folded twice diagonally into the shape of a cornet, having the angular parts rounded off. Or the piece of paper being cut into a circle, may be folded fan-like from the centre, with the folds placed exteriorly, and turned out sharp by the pressure of the finger and thumb, to keep intervals between the paper and the funnel into which it is fitted, to favor the percolation. The diameter of the funnel should be about three fourths of its height, measured from the neck to the edge. If it be more divergent, the slope will be too small for the ready efflux of the fluid. A filter covered with the sediment is most conveniently washed by spouting water upon it with a little syringe. A small camel's-hair paint brush is much employed for collecting and turning over the contents in their soft state. Agitation or vibration is of singular efficacy in quickening percolation, as it displaces the particles of the moistened powders, and opens up the pores which had become closed. Instead of a funnel, a cylindrical vessel may be employed, having its perforated bottom covered with a disc of filtering powder folded up at the edges, and made tight there by a wire ring. Linen or calico is used for weak alkaline liquors; and flannels, twilled woollen cloth, or felt-stuff, for weak acid ones. These filter bags are often made conical like a fool's cap, and have their mouths supported by a wooden or metallic hoop. Cotton wool put loose into the neck of a funnel answers well for filtering oils upon the small scale. In the large way, oil is filtered in conical woollen bags, or in a cask with many conical tubes in its bottom, filled with tow or cotton wool. Stronger acid and alkaline liquors must be filtered through a layer of pounded glass, quartz, clean sand, or bruised charcoal. The alcarrhazas are a porous biscuit of stone ware made in Spain, which are convenient f r filtering water, as also the porous filtering stone of Teneriffe, largely imported into England at one time, but now superseded in a great measur eby the artificial filters patented under many forms, consisting essentially of strata of gravel, sand, and charcoal powder.

It is convenient to render the filter self-acting, by accommodating the supply of liquid to the rate of percolation, so that the pressure upon the porous surface may be always equally great. Upon the small scale, the lamp-fountain or bird's-glass form, so generally used for lamps, will be found to answer.

Fig. 529 represents a glass bottle, A, partly filled with the fluid to be filtered, supported in the ring of a chemical stand, and having its mouth inverted into the same liquor in the filter funnel. It is obvious that whenever this liquor by filtration falls below the lip of the bottle, air will enter into it, let down a fresh supply to feed the filter, and keep the funnel regularly charged. If larger quantities are to be operated upon, the following apparatus may be employed. *Fig.* 530, A B, is a metallic vessel which may be made air-tight; C is the under pipe, provided with a stopcock, R, for letting down the liquor into the filter *a b*. The upper pipe *t*, through which the fluid is poured by means of the funnel E, has also a stopcock which opens or shuts, at the same time, the small side tube *u t*, through which, during the entrance of the fluid, the air is let off from the receiver. A glass tube, *g*, shows the level of the liquor in the body of the apparatus. In using it, the cock R must be first closed, and the cock S must be opened to fill the receiver. Then the filter is set a going, by re-opening the cock R, so as to keep the fluid in the filter upon a level with the opening of the tube C. Both these pieces of apparatus are essentially the same.

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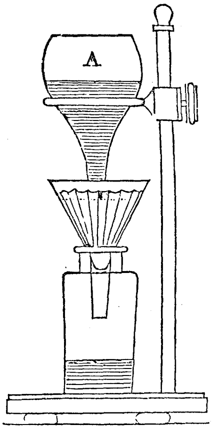

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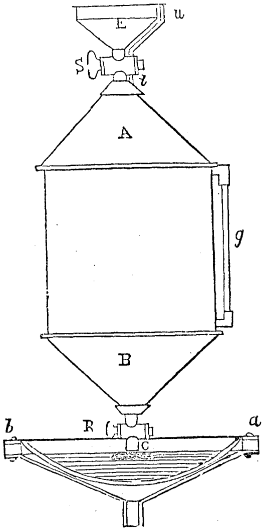

In many manufactures, self-acting filters are fed by the plumber's common contrivance of a ball-cock, in which the sinking and rising of the ball, within certain limits, serves to open or shut off the supply of liquor, as it may be required or not. Dumont has adopted this expedient for his system of filtering sirup through a stratum of granularly ground animal charcoal or bone-black. *Fig.* 531 is a front view of this apparatus with 4 filters, C; and *fig.* 532 is a cross section. The frame-work B supports the cistern A, in which the sirup is contained. From it the liquor flows through the stopcock

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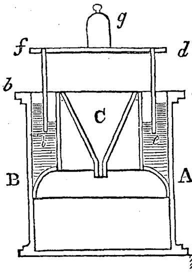

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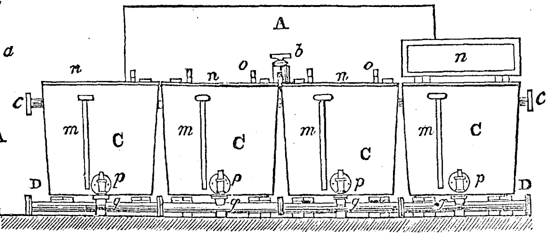

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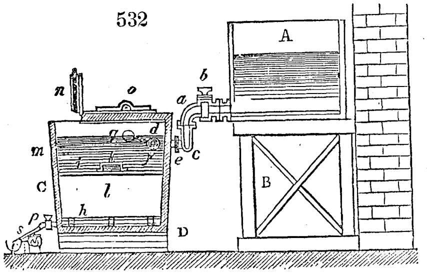

b, and the connexion-tube *a*, into the common pipe *c*, which communicates, by the short branch tubes *e*, with each of the four filters. The end of the branch tube, which is inside of the filter tub, is provided with a stop-cock *d f*, whose opening, and thereby the efflux of the liquor from the cistern through the tube *a*, is regulated by means of the float-ball *g*. Upon the brickwork D the filter tub stands, furnished at *h* with a false bottom of zinc or copper pierced with fine holes; besides which, higher up at *i* there is another such plate of metal furnished with a strong handle *k*, by which it may be removed, when the bone black needs to be changed. In the intervening space *l*, the granular coal is placed. *o* is the cover of the filter tub, with a handle also for lifting it. One portion of it may be raised by a hinge, when it is desired to inspect the progress of the filtration within. *m m* is a slender vertical tube, forming a communication between the bottom part *h*, and the upper portion of the filter, to admit of the easy escape of the air from that space, and from among the bone black as the sirup descends; otherwise the filtration could not go on. *p* is the stopcock through which the fluid collected in the space under *h*, is let off from time to time into the common pipe *q*, *fig.* 531. *r* is a trickling channel or groove lying parallel to the tube *q*, and in which, by means of a tube *s*, inserted at pleasure, the sirup is drawn off in case of its flowing in a turbid state, when it must be returned over the surface of the charcoal.

The celerity with which any fluid passes through the filter depends, 1. upon the porosity of the filtering substance; 2. upon the pressure exercised upon it; and 3. upon the extent of the filtering surface. Fine powders in a liquor somewhat glutinous, or closely compacted, admit of much slower filtration than those which are coarse and free; and the former ought, therefore, to be spread in a thinner stratum and over a more extensive surface than the latter, for equal effect; a principle well exemplified in the working of Dumont's apparatus, just described.

In many cases filtration may be accelerated by the increase of hydrostatic or pneumatic pressure. This happens when we close the top of a filtering cylinder, and connect it by a pipe with a cistern of fluid placed upon a higher level. The pressure of the air may be rendered operative also either by withdrawing it partially from a close vessel, into which the bottom of the filter enters, or by increasing its density over the top of the liquor to be filtered. Either the air pump or steam may be employed to create a partial void in the receiver beneath the filter. In like manner, a forcing pump or steam may be employed to exert pressure upon the surface of the filtering liquor. A common syphon may, on the same principle, be made a good pressure filter, by making its upper leg trumpet-shaped, covering the orifice with filter paper or cloth, and filling the whole with liquor, the lower leg being of such length so as to create considerable pressure by the difference of hydrostatic level. This apparatus is very convenient either on the small or great scale, for filtering off a clear fluid from a light muddy sediment. The pressure of the atmosphere may be elegantly applied to common filters, by the apparatus represented in *fig.* 533, which is merely a funnel enclosed within a gasometer. The case A B bears an annular hollow vessel *a b*, filled with water, in which receiver the cylindrical gasometer *d*, *e*, *f*, *i*, is immersed. The filter funnel is secured at its upper edge to the inner surface of the annular vessel *a b*. In consequence of the pressure of the gasometer regulated by the weight *g*, upon the air enclosed within it, the liquid is equally pressed, and the water in the annular space rises to a corresponding height on the outer surface of the gasometer, as shown in the figure. Were the apparatus made of sheet iron, the annular space might be charged with mercury.

In general, relatively to the application of pressure to filters, it may be remarked, that it cannot be pushed very far, without the chance of deranging the apparatus, or rendering the filtered liquor muddy. The enlargement of the surface is, generally speaking, the safest and most efficacious plan of increasing the rapidity of filtration, especially for liquids of a glutinous nature. This expedient is well illustrated in the creased bag filter now in use in most of the sugar refineries of London. See SUGAR.

In many cases it is convenient so to construct the filtering apparatus, as that the liquid shall not descend, but mount by hydrostatic pressure. This method has two advantages: 1. that without much expensive apparatus, any desired degree of hydrostatic pressure may be given, as also that the liquid may be forced up through several filtering surfaces placed alongside of each other; 2. that the object of filtering, which is to separate the particles floating in the fluid without disturbing the sediment, may be perfectly attained, and thus very foul liquids be cleared without greatly soiling the filtering surface.

Such a construction is peculiarly applicable to the purification of water, either alone, or combined with the downwards plan of filtration. Of the former variety an example is shown in *fig.* 534. The wooden or zinc conical vessel is provided with two perforated bottoms or sieves *e e*, betwixt which the filtering substance is packed. Over this, for the formation of the space *h h*, there is a third shelf, with a hole in its middle, through which the tube *d b* is passed, so as to be water tight. This places the upper open part of the apparatus in communication with the lowest space *a*. From the compartment *k h* a small air tube *l* runs upwards. The filtering substance consists at bottom of pebbles, in the middle of gravel, and at the top of fine sand, which may be mixed with coarsely ground bone black, or covered with a layer of the same. The water to be filtered being poured into the cistern at top, fills through the tube *b d* the inferior compartment *a*, from which the hydrostatic pressure forces the water upward through the perforated shelf, and the filtering materials. The pure water collects in the space *h h*, while the air escapes by the small tube *l*, as the liquid enters. The stopcock *i* serves to draw off the filtered water. As the motion of the fluid in the filter is slow, the particles suspended in it have time to subside by their own gravity; hence there collects over the upper shelf at *d*, as well as over the under one at *a*, a precipitate or deposite which may be washed out of the latter cavity by means of the stopcock *m*.

As an example of an upwards and downwards filter, *fig.* 535 may be exhibited. A B C D is a wooden or metallic cistern furnished with the perforated shelf *c d* near its under part, upon which a vertical partition is fixed through the axis of the vessel. A semicircular perforated shelf is placed at *a*, and a second similar one at *b*. These horizontal shelves rest upon brackets in the sides of the cisterns, so that they may be readily lifted out. The space G is filled with coarse sand, J with moderately fine, and H with very fine The foul water is poured into the chamber E, and presses through G J H and into the space F; whence it may be drawn by the stopcock *f*.

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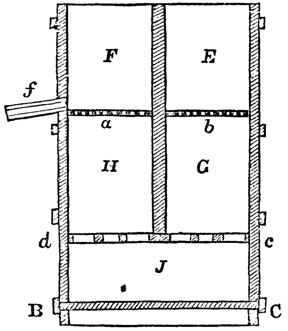

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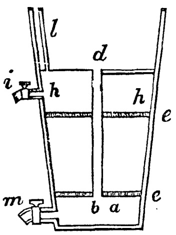

Fig. 536 represents in section a filtering apparatus consisting of two concentric chambers; the interior being destined for downwards filtration, and the exterior for upwards. Within the larger cistern A, a smaller one B is placed concentrically, with its under part, and is left open from distance to distance, to make a communication between the interior cavity and the exterior annular space. These cavities are filled to the marked height with sand and gravel. The inner cylindrical space has fine sand below, then sharper sand with granular charcoal, next coarse sand, and lastly gravel. The annular space has in like manner fine sand below. The foul water is introduced by the pipe E, the orifice at whose end is acted upon by a ball-cock with its lever *a*; whereby the water is kept always at the same level in the inner vessel. The water sinks through the sand strata of the middle vessel, passes outwards at its bottom into the annular space, thence up through the sand in it, and collecting above it, is let off by the stopcock on the pipe *b*. When a muddy deposite forms after some time, it may be easily cleared out. The cord *e*, running over the pulleys *f f*, being drawn tight, the ball lever will shut up the valve. The stopcock *d* made fast to the conducting tube E must then be opened, so that the water now overflows into the annular space at A; the tube *c*, in communication with the inner space B, being opened by taking out the stopper *h*. The water thereby percolates through the sand strata in the reverse direction of its usual course, so as to clear away the impurities in the space B, and to discharge them by the pipe *c h*. An apparatus of this kind of moderate size is capable of filtering a great body of water. It should be constructed for that purpose of masonry; but upon a small scale it may be made of stone-ware.

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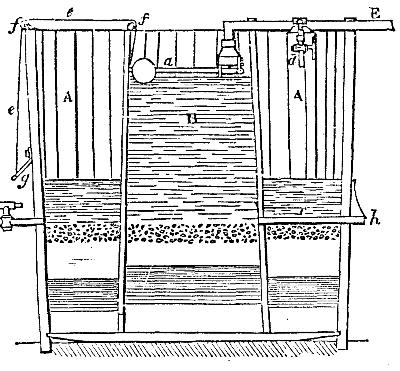

A convenient apparatus for filtering oil upwards is represented in *fig.* 537. *g* is an oil cask, in which the impure parts of the oil have accumulated over the bottom. Immediately above this, a pipe *a* is let in, which communicates with an elevated water cistern

n. *f* is the filter (placed on the lid of the cask), furnished with two perforated shelves, one at *e* and another at *d;* which divide the interior of the filter into three compartments. Into the lower space immediately over the shelf *e*, the tube *b*, furnished with a stopcok, enters, to establish a communication with the cask; the middle cavity *e* is filled with coarsely ground charcoal or other filtering materials: and the upper one has an eduction pipe, *l*. When the stopcocks of the tubes *a* and *b* are opened, the water passes from the cistern into the oil cask, occupies from its density always the lowest place, and presses the oil upwards, without mixing the two liquids; whereby first the upper and purer portion of the oil is forced through the tube *b* into the filter, and thence out through the pipe *l*. When the fouler oil follows, it deposites its impurities in the space under the partition *c*, which may from time to time be drawn off through the stopcock *k*, while the purer oil is pressed upwards through the filter. In this way the different strata of oil in the cask may be filtered off in succession, and kept separate, if found necessary, for sale or use, without running any risk of mixing up the muddy matter with what is clear. According to the height of the water cistern *n*, will be the pressure, and, of course, the filtering force. When the filter gets choked with dirt, it may be easily recharged with fresh materials.

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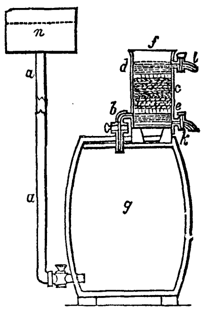


In filtering caustic alkaline leys through linen or quartz, it is proper to exclude the free contact of air; which is done by enclosing the upper vessel, and attaching a pipe of communication between its cover and the shoulder of the lower vessel or recipient of the leys. In proportion as these flow down, they will displace their bulk of air, and drive it into the top of the upper vessel above the foul leys.

Many modifications of the above described apparatus are now on sale in this country; but certainly the neatest, most economical, and effective means of transforming the water of a stagnant muddy pool into that of a crystalline fountain, is afforded by the Royal Patent Filters of George Robins.

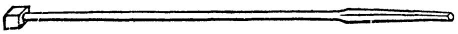
FIRE ARMS, Manufacture of. This art is divided into two branches, that of the metallic and of the wooden work. The first includes the barrel, the lock, and the mounting, as also the bayonet and ramrod, with military arms. The second comprises the stock, and in fowling pieces, likewise the ramrod.

1. *The Barrel.* Its interior is called the bore; its diameter, the calibre; the back end, the breech; the front end, the muzzle; and the closing of the back end, the breech pin or plug. The barrel is generally made of iron. Most military muskets and low-priced guns are fashioned out of a long slip of sheet-iron, folded together edgewise round a skewer into a cylinder, are then lapped over at the seam, and welded at a white heat. The most ductile and tenacious soft iron, free from all blemishes, must be selected for this slip. It is frequently welded at the common forge, but a proper air-furnace answers better, not being so apt to burn it. It should be covered with ashes or cinders. The shape of the bore is given by hammering the cylinder upon a steel mandril, in a groove of the anvil. Six inches of the barrel at either end are left open for forming the breech and the muzzle by a subsequent welding operation; the extremity put into the fire being stopped with clay, to prevent the introduction of cinders. For every length of two inches there are from two to three welding operations, divided into alternating high and low heats; the latter being intended to correct the defects of the former. The breech and muzzle are not welded upon the mandril, but upon the horn of the anvil; the breech being thicker in the metal, is more highly heated, and is made somewhat wider to save labor to the borer. The barrel is finally hammered in the groove of the anvil without the mandril, during which process it receives a heat every two minutes. In welding, the barrel extends about one third in length; and for muskets, is eventually left from 3 to 3½ feet long; but for cavalry pistols, only 9 inches.

The best iron plates for gun-barrels are those made of *stub* iron, that is, of old horse-shoe nails welded together, and forged into thin bars, or rather narrow ribands. At one time *damascus* barrels were much in vogue; they were fashioned either as above described, from plates made of bars of iron and steel laid parallel, and welded together, or from ribands of the same damascus stuff coiled into a cylinder at a red heat, and then welded together at the seams. The best modern barrels for fowling pieces are constructed of stub-nail iron in this manner. The slip or fillet is only half an inch broad, or sometimes less, and is left thicker at the end which is to form the breech, and thinner at the end which is to form the muzzle, than in the intermediate portion. This fillet being moderately heated to increase its pliancy, is then lapped round the mandril in a spiral direction till a proper length of cylinder is formed; the edges being made to overlap a little in order to give them a better hold in the welding process. The coil being taken off the mandril and again heated, is struck down vertically with its muzzle end upon the anvil, whereby the spiral junctions are made closer and more uniform. It is now welded at several successive heats, hammered by horizontal strokes, called *jumping*, and brought into proper shape on the mandril. The finer barrels are made of still narrower stub-iron slips, whence they get the name of wire twist. On the Continent, barrels are made of steel wire, welded together lengthwise, then coiled spirally into a cylinder. Barrels that are to be rifled require to be made of thicker iron, and that of the very best quality, for they would be spoiled by the least portion of scale upon their inside. Soldiers' muskets are thickened a little at the muzzle, to give a stout holding to the bayonet.

The barrels thus made are annealed with a gentle heat in a proper furnace, and slowly cooled. They are now ready for the borer, which is an oblong square *bit* of steel, pressed in its rotation against the barrel, by a slip of wood applied to one of its flat sides, and held in its place by a ring of metal. The boring bench works horizontally, and has a very shaky appearance, in respect at least of the bit. In some cases, however, it has been attempted to work the barrels and bits at an inclination to the horizon of 30°, in order to facilitate the discharge of the borings. The barrel is held in a slot by only one point, to allow it to humor the movements of the borer, which would otherwise be infallibly broken. The bit, as represented in *fig.* 538, has merely its square head inserted into a clamp-chuck of the lathe, and plays freely through the rest of its length.

538



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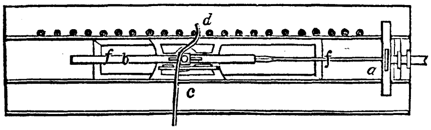

Fig. 539 represents in plan the *boring bench* for musket barrels; *f f* is the sledge or carriage frame in which the barrel is supported; *a* is the revolving chuck of the lathe, into which the square end of the bit, *fig.* 538, is inserted; *b* is the barrel, clamped at its middle to the carriage, and capable of being pressed onwards against the tapering bit of the borer, by the bent lever *c*, worked by the left hand of the operative against fulcrum knobs at *d*, which stand about two inches asunder. Whenever the barrel has been thereby advanced a certain space to the right, the bent end of the lever is shifted against another knob or pin. The borer appears to a stranger to be a very awkward and unsteady mechanism, but its perpetual vibrations do not affect the accuracy of the bore. The opening broach may be of a square or pentagonal form, and either gradually tapered from its thickest part, or of uniform diameter till within two inches of the end, whence it is suddenly tapered to a point.

A series of bits may be used for boring a barrel, beginning with the smallest and ending with the largest. But this multiplication of tools becomes unnecessary, by laying against the cutting part of the bit slips of wood, called spales, of gradually increasing thickness, so that the edge is pressed by them progressively further from the axis. The bore is next polished. This is done by a bit with a very smooth edge, which is mounted as above, with a wedge of wood besmeared with a mixture of oil and emery. The inside is finished by working a cylindrical steel file quickly backwards and forwards within it, while it is revolving slowly.

In boring, the bit must be well oiled or greased, and the barrel must be kept cool by letting water trickle on it; for the bit, revolving at the rate of 120 or 140 times a minute, generates a great deal of heat. If a flaw be detected in the barrel during the boring, that part is hammered in, and then the bit is employed to turn it out.

Many sportsmen are of opinion that a barrel with a bore somewhat narrowed towards the muzzle serves to keep shot better together; and that roughening its inside with pounded glass has a good effect, with the same view. For this purpose, also, fine spiral lines have been made in their interior surface. The justness of its calibre is tried by means of a truly turned cylinder of steel, 3 or 4 inches long, which ought to move without friction, but with uniform contact from end to end of the barrel. Whatever irregularities appear must be immediately removed.

The outer surface of the barrel is commonly polished upon a dry grindstone, but it is better finished, and less dangerously to the workman, at a turning lathe with a slide rest. If a stone be used, it should be made to revolve at the mouth of a tunnel of some kind, into which there is a good draught to carry off the ferruginous particles. A piece of moist cloth or leather should be suspended before the orifice.

Rifle barrels have parallel grooves of a square or angular form cut within them, each groove being drawn in succession. These grooves run spirally, and form each an aliquot part of a revolution from the chamber to the muzzle. Rifles should not be too deeply indented; only so much as to prevent the ball turning round within the barrel and the spires should be truly parallel, that the ball may glide along with a regular pace. See *infra.*

The Parisian gun-makers, who are reckoned very expert, draw out the iron for the barrels at hand forges, in fillets only one ninth of an inch thick, one inch and a half broad, and four feet long. Twenty-five of these ribands are laid upon each other, between two similar ones of double thickness, and the bundle, weighing 60 pounds, bound with wire at two places, serves to make two barrels. The thicker plates are intended to protect the thinner from the violence of the fire in the numerous successive heats necessary to complete the welding, and to form the bundle into a bar two thirds of an inch broad, by half an inch thick; the direction of the individual plates relatively to the breadth being preserved. This bar, folded flat upon itself, is again wrought at the forge, till it is only half an inch broad, and a quarter of an inch thick, while the plates of the primitive ribands are now set perpendicular to the breadth of the narrow fillet; the length of which must be 15 or 16 feet French (16 or 17 English), to form a fowling piece from 28 to 30 inches long. This fillet, heated to a cherry red in successive portions, is coiled into as close a spiral as possible, upon a mandril about two fifths of an inch in diameter. The mandril has at one end a stout head for drawing it out, by means of the hammer and the grooves of the anvil, previous to every heating. The welding is performed upon a mandril introduced after each heat; the middle of the barrel being first worked, while the fillets are forced back against each other, along the surface of the mandril, to secure their perfect union. The original plates having in the formation of the ultimate long riband become very thin, appear upon the surface of the barrel like threads of a fine screw, with blackish tints to mark the junctions. In making a double-barrelled gun, the two are formed from the same bundle of slips, the coils of the one finished fillet being turned to the right hand, and those of the other to the left.

The Damascus barrels forged as above described, from a bundle of steel and iron plates laid alternately together, are twisted at the forge several times, then coiled and welded as usual. Fifteen Parisian workmen concur in one operation: six at the forge; two at the boring mill; seven at filing, turning, and adjusting; yet all together make only six pairs of barrels per week, which are sold at from 100 to 300 francs the pair, ready for putting into the stock.

The breeching is of three kinds: the common; the chamber, plug, or mortar, *fig.* 540; and the patent, *fig.* 541. The common was formerly used for soldiers' muskets and inferior pieces. The second is a trifling improvement upon it. In the patent breeching, the screws do not interfere with the touch-hole, and the ignition is quicker in the main chamber.

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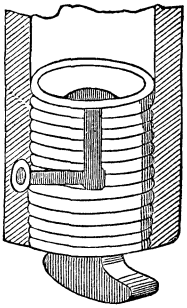

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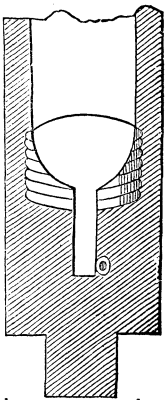

The only locks which it is worth while to describe are those upon the percussion principle, as flint locks will certainly soon cease to be employed even in military muskets. Forsyth's lock (*fig.* 542) was an ingenious contrivance. It has a magazine *a*, for containing the detonating powder, which revolves round a roller *b*, whose end is screwed into the breech of the barrel. The priming powder passes through a small hole in the roller, which leads to a channel in communication with the chamber of the gun. The pan for holding the priming is placed immediately over the little hole in the roller. There is a steel punch *c*, in the magazine, whose under end stands above the pan, ready

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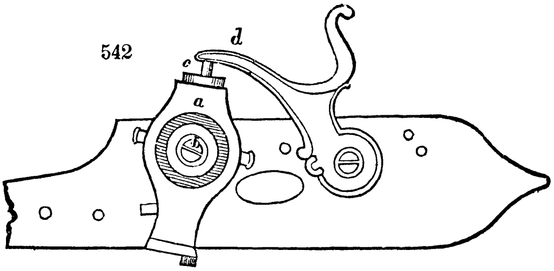

to ignite the priming when struck upon the top by the cock *d*, whenever the trigger is drawn. The punch immediately after being driven down into the pan is raised by the action of a spiral spring. For each explosion, the magazine must be turned so far round as to let fall a portion of the percussion powder into the pan; after which it is turned back, and the steel punch recovers its proper position for striking another blow into the pan.

The invention of the copper percussion cap was another great improvement upon the detonating plan. *Fig.* 543 represents the ordinary percussion lock, which is happily divested of three awkward projections upon the flint lock, namely, the hammer, hammer spring, and the pan. Nothing now appears upon the plate of the lock, but the cock or striking hammer, which inflicts the proper blow upon the percussion cap. It is concave, with a small metallic ring or border, called a shield or fence, for the purpose of enclosing the cap, as it were, and preventing its splinters doing injury to the sportsman, as also protecting against the line of flame which may issue from the touch-hole in the cap nipple. This is screwed into the patent breech, and is perforated with a small hole.

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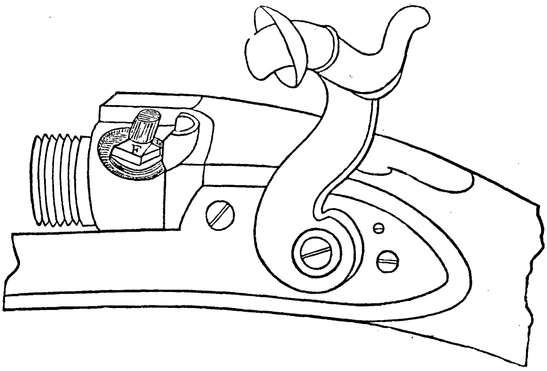
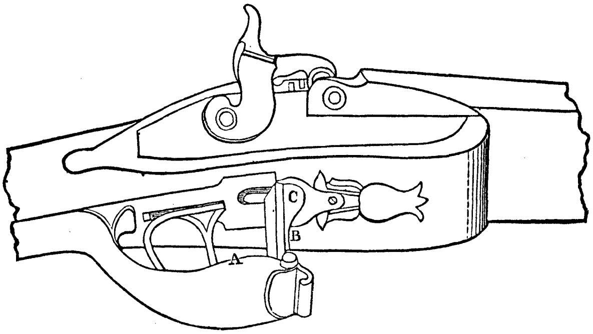


The safety lock of Dr. Somerville is a truly humane invention. Its essential feature is a slide stop or catch, placed under the trigger A, *fig.* 544. It is pulled forward into a notch in the trigger, by means of a spring B, upon the front of the guard, which is worked by a key c, pressing upon the spring when the piece is discharged. In another safety plan there is a small moveable curved piece of iron, A, which rises through an opening B, in the lock-plate c, and prevents the cock from reaching the nipple, as represented in the figure, until it is drawn back within the plate of the lock when the piece is fired.

544



To fire this gun, two different points must be pressed at the same time. If by accident the key which works the safety be touched, nothing happens, because the trigger is not drawn; and the trigger touched alone can produce no effect, because it is locked. The pressure must be applied to the trigger and the key at the same instant, otherwise the lock will not work.

The French musket is longer than the British, in the proportion of 44·72 inches to 42; but the French bayonet is 15 inches, whereas the British is 17.

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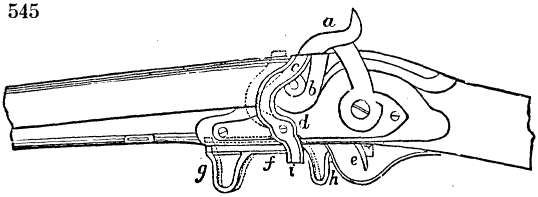
	Eng. Dimensions.	Fr. Dimensions.
Diameter of the bore - - - - -	0.75 in.	0·69 in.
Diameter of the ball - - - - -	0·676	0·65
Weight of the ball in oz. - - - -	1·06	0·958
Weight of the firelock and bayonet in lbs. -	12·25	10·980
Length of the barrel and bayonet - · -	59·00	59·72

Within these few years a great many contrivances have been brought forward, and several have been patented for fire arms. The first I shall notice is that of Charles Random, Baron de Berenger. *Fig.* 545 shows the lock and breech of a fowling piece, with a sliding protector on one of the improved plans; *a* is the hammer, *b* the nipple of the touch-hole, *c* a bent lever, turning upon a pin, fixed into the lock-plate at *d*. The upper end of this bent lever stands partly under the nose of the hammer, and while in that situation stops it from striking the nipple. A slider *g f h*, connected with the under part of the gun-stock, is attached to the tail of the bent lever at *i*; and when the piece is brought to the shoulder for firing, the hand of the sportsman pressing against the bent part of the slider at *g*, forces this back, and thereby moves the end of the lever *c* forward from under the nose of the cock or hammer, as shown by the dotted lines. The trigger being now drawn, the piece will be discharged; and on removing the hand from the end *g*, of the slider *f*, the spring at *h* acting against the guard, will force the slider forward, and the lever into the position first described.

545



Mr. Redford, gun-maker of Birminghan, proposes a modification of the lock for small fire-arms, in which the application of pressure to the sear spring for discharging the piece is made by means of a plug, depressed by the thumb, instead of the force of the finger exerted against the trigger. *Fig.* 546 represents a fowling piece partly in section. The sear spring is shown at *a*. It is not here connected with the trigger as in other locks; but is attached by a double-jointed piece to a lever *b*, which turns upon a fulcrum pin in its centre. At the reverse end of this lever an arm extends forwards, like that of an ordinary sear spring, upon which arm the lower end of the plug *c* is intended to bear; and when this plug is depressed by the thumb bearing upon it, that end of the lever *b* will be forced downwards, and the reverse end will be raised, so as to draw up the end of the sear spring, and set off the piece. For the sake of protection, the head of the plug *c* is covered by a moveable cap *d*, forming part of a slider *e*, which moves to and fro in a groove in the stock, behind the breech end of the barrel; this slider *e* is acted upon by the trigger through levers, which might be attached to the other side of the lock-plate; but are not shown in this figure, to avoid confusion. When the piece is brought to the shoulder for firing, the fore-finger must be applied as usual to the trigger, but merely for the purpose of drawing back the slider *e*, and uncovering the head of the plug; when this is done, the thumb is to be pressed upon the head of the plug, and will thus discharge the piece. A spring bearing against the lever of the slider *e*, will, when the finger is withdrawn from the trigger, send the slider forward again, and cover the head of the plug, as shown.

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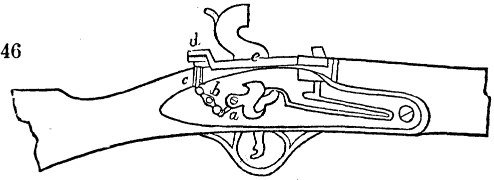
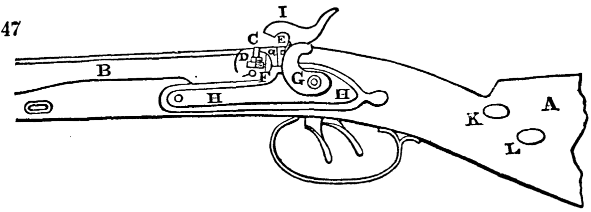


It is with pleasure I again advert to the humane ingenuity of the Rev. John Somerville, of Currie. In April, 1835, he obtained a patent for a further invention to prevent the accidental discharge of fire arms. It consists in hindering the hammer from reaching the nipple of a percussion lock, or the flint reaching the steel of an ordinary one, by the interposition of moveable safety studs or pins, which protrude from under the false breech before the hammers of the locks, and prevent them from descending to strike.

These safety studs or pins are moved out of the way by the pressure of the right hand of the person using the gun only when in the act of firing, that is, when the force of the right hand and arm is exerted to press the butt end of the stock of the gun against the shoulder while the aim is taken and the trigger pulled. In carrying the gun at rest, the proper parts of the thumb or hand do not come over Mr. Somerville's moveable buttons or studs.

Fig. 547 is a side view of part of a double percussion gun; and *fig.* 548 is a top or plan view, which will serve to explain these improvements, and show one, out of many, methods of carrying them into effect. A is the stock of the gun; B the barrels; C the breech; D the nipples; E the false breech, on the under side of which the levers which work the safety studs or pins are placed; F is the shield of the false breech; G, triggers; H the lock-plate; and I the hammers: all of which are constructed as usual: *a a* are the safety studs or pins, which protrude before the shield F, and work through guide pieces on the under side of the false breech. The button piece is placed in the position for the thumb of the right hand to act upon it; but when the pressure of the ball of the right thumb is to produce the movement of the safety studs, it must be placed in or near the position K; and when the heel of the right hand is to effect the movements of the safety studs, the button piece must be placed at L, or nearly so.

547



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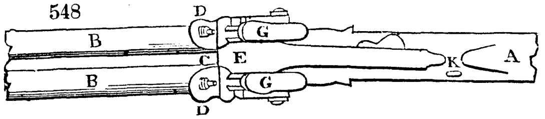

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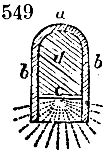

In these last two positions, the lever (which is acted upon by the button piece to work the safety studs through a slide) would require to be of a different shape and differently mounted. When the hammers are down upon the nipples after discharging the gun, the ends of the safety pins press against the inner sides of the hammers. When this invention is adapted to single-barrelled guns, only one pin, *a*, one lever and button piece will be required.

Mr. Richards, gun maker, Birmingham, patented, in March, 1836, a modification of the copper cap for holding the percussion powder, as represented *fig.* 549; in which the powder is removed from the top of the cap, and brought nearer the mouth; *a* being the top, *b* the sides, and *c* the position of the priming. The dotted lines show the direction of the explosion, whereby it is seen that the metal case is opened or distended only in a small degree, and not likely to burst to pieces, as in the common caps, the space between *a* and *c* being occupied by a piece of any kind of hard metal *d*, soldered or otherwise fastened in the cap.

George Lovell, Esq., director of the Royal Manufactory of Arms at Enfield, has recently made a great improvement upon the priming chamber. He forms it into a vertical double cone, joined in the middle by the common apex; the base of the upper cone being in contact with the percussion cap, presents the most extensive surface to the fulminate upon the one hand, while the base of the under one being in a line with the interior surface of the barrel, presents the largest surface to the gunpowder charge, upon the other. In the old nipple the apex of the cone being at its top, afforded very injudiciously the *minimum* surface to the exploding force.

Guns, Rifling of the Barrels. — The outside of rifle barrels is, in general, octagonal, After the barrel is bored, and rendered truly cylindrical, it is fixed upon the rifling machine. This instrument is formed upon a square plank of wood 7 feet long, to which is fitted a tube about an inch in diameter, with spiral grooves deeply cut internally through its whole length; and to this a circular plate is attached, about 5 inches diameter, accurately divided in concentric circles, into from 5 to 16 equal parts, and supported by two rings made fast to the plank, in which rings it revolves. An arm connected with the dividing graduated plate, and pierced with holes, through which a pin is passed, regulates the change of the tube in giving the desired number of grooves to the barrel. An iron rod, with a moveable handle at the one end, and a steel cutter in the other, passes through the above rifling tube. This rod is covered with a core of lead one foot long. The barrel is firmly fixed by two rings on the plank, standing in a straight line on the tube. The rod is now drawn repeatedly through the barrel, from end to end, until the cutter has formed one groove of the proper depth. The pin is then shifted to another hole in the dividing plate, and the operation of grooving is repeated till the whole number of riflings is completed. The barrel is next taken out of the machine, and finished. This is done by casting upon the end of a small iron rod a core of lead, which, when besmeared with a mixture of fine emery and oil, is drawn, for a considerable time, by the workmen, from the one end of the barrel to the other, till the inner surface has become finely polished. The best degree of spirality is found to be from a quarter to half a revolution in a length of three feet.

Military Rifles.—An essential improvement in this destructive arm has lately been introduced into the British service at the suggestion of Mr. Lovell.

The intention in all rifles is to impart to the ball a rotatory or spinning motion round its axis, as it passes out through the barrel. This object was attained, to a certain degree, in the rifles of the old pattern, by cutting seven spiral grooves into the inside of the barrel, in the manner shown by *fig.* 550, the spherical ball, *fig.* 551, being a little larger than the bore, was driven down with a mallet, by which the projecting ribs were forced into the surface of the ball, so as to keep it in contact with their curvatures, during its expulsion. Instead of this laborious and insecure process, the barrel being now cut with only two opposite grooves, *fig.* 552, and the ball being formed with a projecting belt, or zone, round its equator, of the same form as the two grooves, *fig.* 553, it enters so readily into these hollows, that little or no force is required to press it down upon the powder. So much more hold of the barrel is at the same time obtained, that instead of one *quarter* of a turn, which was the utmost that could be safely given in the old way, without danger of stripping the ball, a *whole* turn round the barrel, in its length, can be given to the two grooved rifles; whereby a far more certain and complete rotatory motion is imparted to the ball. The grand practical result is, that better practice has been performed by several companies of the Rifle Corps, at 300 yards, than could be produced with the best old military rifles at 150 yards; the soldier being meanwhile enabled to load with much greater ease and despatch. The belt is bevelled to its middle line, and not so flat as shown in the figure.

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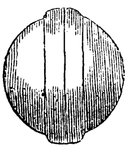

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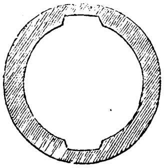

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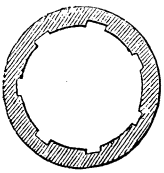

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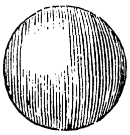

This mode of rifling is not, however, new in England. In fact, it is one of the oldest upon record; and appears to have fallen into disuse from faults in the execution. The idea was revived within the last few years in Brunswick, and it was tried in Hanover also, but with a lens-shaped (Linsenförmig) ball. The judicious modifications and improvements it has finally received in Mr. Lovell's hands, have brought out all its

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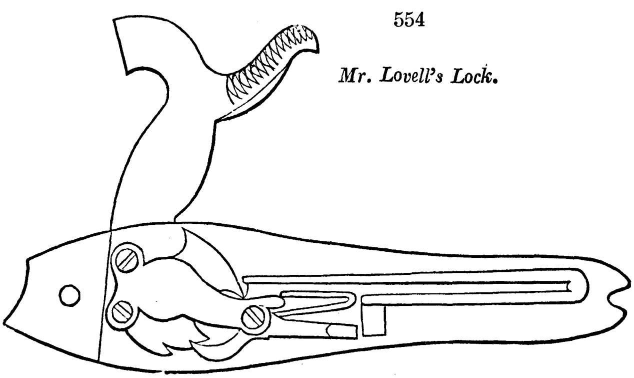


Mr. Lovell's Lock.

advantages, and rendered it, when skilfully used, a weapon of unerring aim, even at the prodigious distance of 700 yards.

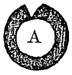
The locks, also, for the military service generally, are now receiving an important improvement by means of his labors, having been simplified in a remarkable manner. The action of the main spring is reversed, as shown by *fig.* 554; thus rendering the whole mechanism more solid, compact, and convenient; while the ignition of the charge being effected by percussion powders in a copper cap, the fire of the British line will, in future, be more murderous than ever, as a miss-fire is hardly ever experienced with the fire-arms made at the Royal manufactury, under Mr. Lovell's skilful superintendence.

Barrel-welding by Machinery.—The barrels of musquets, birding-guns, &c., or what are called *plain*, to distinguish them from those denominated *stub* or twisted barrels, have of late years been formed by means of rolls, a process in which the welding is first effected on a short slab of thick iron, and then the barrel is brought down to its destined length, and form, by repeatedly passing it between a pair of rolls, that have been previously grooved to the exact shape of the barrel intended to be made.

This method has entirely superseded the skelp-welding by hand described in the *Dic. of Man.*, p. 717, and is conducted as follows :—

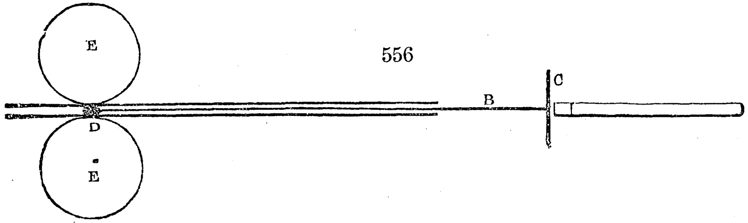
The iron being thoroughly refined, and reduced into flat bars by the process described at length at p. 1079, is cut by the shears into slabs or lengths of 10 to 12 inches, and 10 to 10½ lbs. weight, or less, according to the description of gun-barrel that is intended to be made. These slabs are then heated, and bent in their whole length, by means of conveniently grooved bending rolls, until they assume the form of rough tubes, of the kind of section shown by A, *fig.* 555. They are then placed on the hearth of the reverberatory furnace (*Dict.* p. 1081), and brought to a full welding heat, and as soon as the edges of a tube come to a semi-fluid state, it is taken out and passed between rolls having grooves somewhat smaller in diameter than the exterior of the tube, by which means the tube is perfectly welded from end to end; and if care be taken in the management of the heat, and the juncture be kept clear of dirt and cinders, the iron will be found perfectly homogeneous in every part, and there will be no appearance whatever of the seam where the edges came together. These tubes are repeatedly heated, and passed between the barrel rolls, which are of sufficient diameter to admit of gradually decreasing grooves, the whole length of the intended barrel being indented on their surfaces.

555



To preserve the tubular form, and insure regularity in the size of the bore during the welding process, they are taken out of the furnace, by thrusting into them a tool called a mandril B, which consists of a long rod of iron, having a short steel treblett on its end, of the diameter that the bore of the barrel is meant to bore. This rod is so adjusted by means of a strong iron plate C, near its handle, which is of wood, and long, that when passed with the heated tube on it between two tranverse holding bars, the short steel treblett D, shall be found exactly between the point of impact of the barrel-rolls, E E.

556



The adhesion of the hot iron to the surface of the rolls is strong enough to draw the tube off the mandril, which thus keeps the bore open from end to end, and by repeating the process through the whole series of grooves in the rolls, the barrel is gradually elongated, and brought down to the exact form required: any superfluous length at the muzzle is then cut off. The breach end is then adjusted by the hammer—a tripple-seat welded on by hand if it be intended for a percussion lock, and then the barrel is ready to go forward to the mill to be bored, turned, and finished.

Gun-barrels formed by this mechanical method are found to stand proof better than those worked by hand, because the heat is more equalized; and any imperfections in the original mass of iron are more dispersed over the whole extent of the tube.

Mr. Wells Ingram, of Bradford street, Birmingham, has lately perfected a very complete lathe for turning the exterior of gun-barrels of all descriptions, a process which is

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fast superseding the use of the grindstone, for equalising the barrels of all kinds of fire-arms.

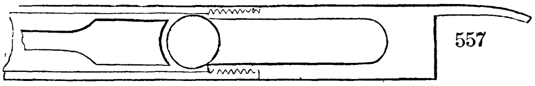
I am indebted for this article to Mr. Lovell, Director of the Royal Arms Manufactory. See Musquet.

Since the first edition of the Dictionary large strides have been made towards increasing the efficacy of military fire arms; the French had found in their skirmishes with Abd-el-Kader in Africa, that the long matchlocks of the Arabs told at fearful odds against their men at distances where the ordinary French musquet was powerless of offence.

After a while it was found that this increased range was due solely to the greater elevation taken by the natives in aiming, and their expertness in judging their distances, taught by long practice and experience; for the Arab arms and ammunition taken at Constantine were found of the rudest construction.

These observations led the French officers of artillery to institute all sorts of experiments to render their small arms more effective; by the adoption of wall-pieces of wider bore; by introducing a more general use of rifled barrels, but at the same time avoiding the tedious method of loading by means of mallets formerly observed with such kind of arms.

The first attempt towards such object was that proposed by M. Delvigne, an officer of the royal ex-guard, (*fig*, 557), in which the upper orifice of the chamber that contained the powder took the form of a cup, wherein the ball (somewhat wider in diameter) was received, and by two or three smart blows of a heavy-headed rammer (also cupped out for the purpose) became expanded latterly, and thus the rotary motion was imparted to it by the spiral grooves of the barrel in passing out. Colonel Poncharra suggested the addition of a wood bottom or sabôt under the ball and a greased woollen patch; and Colonel Thouvesino proposed (*fig.* 558) a steel stem or pillar about 2 inches long inserted into the face of the breech-pin; round this pin, the charge of powder was received, and the diameter of the ball, when resting on the top of the pin was enlarged by the blows of the heavy-headed rammer, as suggested by Delvigne.



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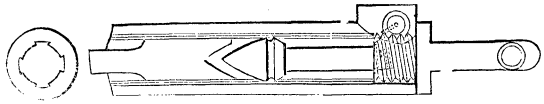


This system took the name of "Carabine à Tige," and has been very generally introduced for the service of fusilier battalions in continental armies; very grave objections, however, have been found against it in use, from the impossibility of keeping the chamber (or post round the pin) clear; and from the severe labor to the soldier in ramming down and enlarging the diameter of the ball sufficiently to ensure the rotary motion desired.

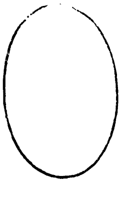
But if the ultimate results thus attained with spherical balls turned out not entirely satisfactory, it was made clearly manifest, in the course of the experiments carried on, that no insuperable difficulty stands in the way of rendering the fire of infantry very much more accurate and powerful, by the use of rifled barrels throughout the army, and thus leading to a verification of the prediction made by Robins above one hundred years ago, that "whatever state shall thoroughly comprehend the nature and advantages of rifled barrel pieces, and having facilitated and completed their construction, shall introduce into their armies their general use, with dexterity in the management of them, will by this means acquire a superiority which will almost equal any thing that has been done at any time."

But besides smoothing the way to such an essential improvement, it has been elicited of late years, that when the accuracy of flight is secured by the rotary motion derived from the rifling, the bullet, instead of being limited to the form of a sphere as heretofore, may, up to certain limits, be elongated with considerable increase of destructive effect; and with an augmentation of range very much beyond anything that has hitherto been considered to lie within the reach of small arms—placing them, in fact, with reference to artillery and cavalry, in the first place instead of the last.

An immensely extended field has thus been opened to experimenters. 1st. Mons. Didon proposed a true oval (*fig.* 559) as the best form of bullet, so that when shortened by the blows of the heavy rammer and widened in its diameter it might be brought nearer to the spherical shape before leaving the barrel.

2d. Mons. Delvigne took a patent for a bullet (*fig.* 560) under the designation of "Cylindro Ogivale;" it had a conical opening behind, in which he imagined that the force of the powder would exert itself with sufficient energy to expand the lead permanently, and so make the ball take the rotary movement derived from the rifling, without any fatigue to the soldier in loading; with this projectile, indeed, the operation is but slightly more difficult than with the ordinary cartridge and smooth barrels.

559



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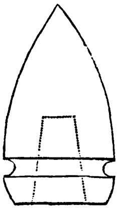

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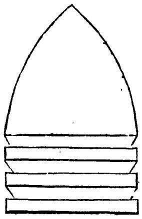

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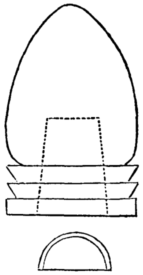

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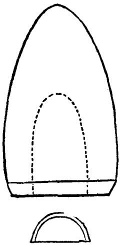

The bullet (*fig.* 561) of the "Carabine à Tige" was called "Cylindro Conique," and was said to possess this advantage over the preceding, that, being brought more to a point in front, it bored its way through the air with greater ease, and thus retained greater velocity, and of course more extended range; and with this bullet it was that Mons. Tamisier introduced three sharp-edged channels round it, which he stated were necessary to keep its flight steady, by offering a resistance to the action of the air.

Finally Mons. Minié, an officer of the French line, suggested (*fig.* 562) the addition of a dénoyau or culot to the hollow ball of Delvigne. This, in the form of a little cup made of sheet iron, is placed in the orifice of the conical hollow of the ball behind, and by the energy of the powder is driven into the ball, enlarging its diameter permanently, and thus giving all the accuracy of the rifle, with nearly the same facility of loading as with the plain barrel.

The principle of the invention, as thus developed, has, we learn, been adopted by our government for the general use of the army, seeing that it offers so great advantages over the system of plain barrels, but the bullet (*fig.* 563), as modified by the Inspector of Small Arms, has on its exterior no channels, they being found not only useless as to steadying the flight of the projectile, but absolutely injurious in lowering its velocity. The bullet in its improved form, too, being more truly balanced in its proportions, and made by mechanical means instead of by casting, has no tendency to the gyrations which appear to have so puzzled French artillerists, and for which they have invented the word "derivation," and wasted much learned disquisition.

Though well satisfied with the results of their course of experiments, our neighbors, however, do not appear to have come to any final decision as yet; indeed, the fact of being able to make use of an elongated projectile with a rifle has let loose such a crowd of inventors, that they seem to be entirely bewildered. In Switzerland every Canton has its peculiar form of bullet, each one, of course, being the best, and from the length and size of a small caterpillar upwards, every man seems to have his own maggot, which he vaunts before the world.

But even if it were ever to happen, which is not likely, that these various projectors could be brought to agree as to the best form of projectile, they will then find out, that although by the general introduction of rifled and elongated bullets an immense advantage has been realised over plain barrels, their plans, based as they all are upon a system of *loading* at the *muzzle*, are at best but one step in advance; and that a good sound military fire-arm *loading* at the *breech* will, after all, remain the great desideratum—an arm that, without any less accuracy or power to reach masses of artillery or cavalry at a thousand yards' distance, will enable the soldier to triple the quantity of his fire at any moment that he may be called upon to repel a charge of cavalry or attack or defend a breach at close quarters; of such simple construction, and so easily handled in every position of the body, that the soldier can pour every shot of his most murderous fire upon the enemy with unerring precision, whilst he himself may lay coolly behind a stone or in a ditch in entire security.

These are no longer wild imaginings, although so many hundreds of attempts towards the same object, from the earliest period to the present day, have been one after another seen invariably to fail. The Germans have been long and steadily pursuing the great object, until at length Herr Dreysa, of Sömmerda in Thuringia, has succeeded, after more than twenty years of continued labor, in establishing a musquet, under the name

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of "Zündnadelgewehr," which if not quite perfect, has been found to work so well in the hands of the men, that the Prussian government has already 80,000 in possession, and they are going on to arm the whole of their line regiments and Landwehr with them.

Even with the assistance of a diagram, it is hardly possible to convey a clear notion of the construction of this musquet, because the several parts work one within the other, and their combination, which is without pin or screw, is hard to comprehend by a mere description.

There is a strong socket, *fig.* 564), *a*, open on the upper side, screwed on to the barrel, *b*, which is rifled in the usual manner; within this socket is a slider *c*, which in fact constitutes the lock, as it contains the spiral spring and mechanism that produces ignition by percussion; it has a stout hebel or handle, by which it is moved backwards and forwards freely.

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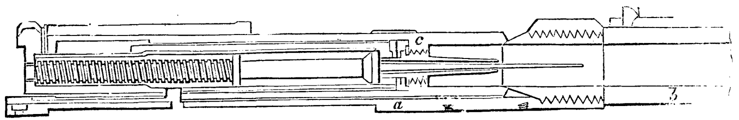

The cartridge (*fig.* 565) consists of the ball *a*, the sabôt *b*, or bottom of hard paper, and holding the priming matter, and lastly the charge of powder, *c*, the whole being made up in paper pasted together. In use, the slider being drawn back, the soldier puts the cartridge with the point of the ball in front into the open breech of the barrel, pushes the slider forward, and secures its close junction by a turn to the right against an inclined edge of the open socket. The spiral spring is then brought into action (or the gun is cocked) by pressing the spring case forward with the thumb.

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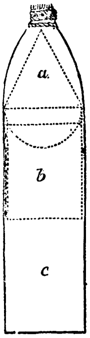

On pulling the trigger, the interior needle, from which the musquet takes its name, is darted forward through the charge of powder into the percussion primer in the sabôt, and thus effects the ignition inside the barrel.

The principle of loading at the *breech* carries with it so many other advantages beyond that by the muzzle, that many ingenious men are occupying themselves with its improvement; Lefaucheur and Robert in France; Montigny in Belgium; Kufahl Schultz and Friedrix in Prussia; Sears and Needham in England, have lately brought forward various plans; and now that the idea is taken up upon a right base, there can be little doubt that eventually a system will be hit upon, that shall secure all the requisites for military service, and avoid all objections.

But it is clear, from the recent publications on gunnery and the observations of *ancient* warriors, that the advocates for heavy battalion movements, for drawing up their infantry in long lines and compact bodies for destruction by artillery, will be with difficulty brought to look with patience upon the scrambling and desultory sort of warfare which the general introduction of these improved rifles must bring about. Time, however, daily goes on to work wonders upon prejudice, and the day will come when it will be found that cross-belts and blank-cartridges may be abolished without utter ruin to the army; and that men behind trees, with effective weapons in their hands, may be more dangerous enemies, at long ranges, than when strapped up and paraded out in masses, and carrying arms that at any distance over 300 are powerless of offence.

FIRE-DAMP; the explosive carburetted hydrogen of coal mines. See Pitcoal.

FIRE-WORKS. (*Feux d'artifice*, Fr.; *Feuerwerke*, Germ.) The composition of luminous devices with explosive combustibles, is a modern art resulting from the discovery of gunpowder. The finest inventions of this kind are due to the celebrated Ruggieri, father and son, who executed in Rome and Paris, and the principal capitals of Europe, the most brilliant and beautiful fire-works that were ever seen. The following description of their processes will probably prove interesting to many of my readers.

The three prime materials of this art are, nitre, sulphur, and charcoal, along with filings of iron, steel, copper, zinc, and resin, camphor, lycopodium, &c. Gunpowder is used either in grain, half crushed, or finely ground, for different purposes. The longer the iron filings, the brighter red and white sparks they give; those being preferred which are made with a very coarse file, and quite free from rust. Steel filings and cast-iron borings contain carbon, and afford a more brilliant fire, with wavy radiations. Copper filings give a greenish tint to flame; those of zinc a fine blue color; the sulphuret of antimony gives a less greenish blue than zinc, but with much smoke; amber affords a yellow fire, as well as colophony, and common salt; but the last must be very dry. Lampblack produces a very red color with gunpowder, and a pink with nitre in excess.

It serves for making golden showers. The yellow sand or glistening mica, communicates to fire-works golden radiations. Verdigris imparts a pale green; sulphate of copper and sal-ammoniac, a palm-tree green. Camphor yields a very white flame and aromatic fumes, which mask the bad smell of other substances. Benzoin and storax are used also on account of their agreeable odor. Lycopodium burns with a rose color and a magnificent flame; but it is principally employed in theatres to represent lightning, or to charge the torch of a fury.

Fire-works are divided into three classes: 1. those to be set off upon the ground; 2. those which are shot up into the air; and 3. those which act upon or under water.

Composition for *jets of fire;* the common preparation for rockets not more than ¾ of an inch in diameter, is; gunpowder, 16 parts; charcoal, 3 parts. For those of larger diameter; gunpowder, 16; steel filings, 4.

Brilliant revolving wheel; for a tube less than ¾ of an inch; gunpowder, 16; steel filings, 3. When more than ¾: gunpowder, 16; filings, 4.

Chinese or Jasmine fire; when less than ¾ of an inch: gunpowder, 16; nitre, 8; charcoal (fine), 3; sulphur, 3; pounded cast-iron borings (small), 10. When wider than ¾: gunpowder, 16; nitre, 12; charcoal, 3; sulphur, 3; coarse borings, 12.

A fixed brilliant; less than ¾ in diameter: gunpowder, 16; steel filings, 4; or, gunpowder, 16; and finely pounded borings, 6.

Fixed suns are composed of a certain number of jets of fire distributed circularly, like the spokes of a wheel. All the fusees take fire at once through channels charged with quick matches. *Glories* are large suns with several rows of fusees. *Fans* are portions of a sun, being sectors of a circle. The *Patte d'oie* is a fan with only three jets.

The *mosaic* represents a surface covered with diamond shaped compartments, formed by two series of parallel lines crossing each other. This effect is produced by placing at each point of intersection, four jets of fire, which run into the adjoining ones. The intervals between the jets must be associated with the discharge of others, so as to keep up a succession of fires in the spaces

Palm trees. Ruggieri contrived a new kind of fire, adapted to represent all sorts of trees, and especially the palm. The following is the composition of this magnificent green fire-work: crystallized verdigris, 4 parts; sulphate of copper, 2; sal-ammoniac, 1. These ingredients are to be ground and moistened with alcohol. An artificial tree of any kind being erected, coarse cotton rovings about 2 inches in diameter, impregnated with that composition, are to be festooned round the trunk, branches, and among the leaves; and immediately kindled before the spirits have had time to evaporate.

Cascades imitate sheets or jets of water. The Chinese fire is best adapted to such decorations.

Fixed stars. The bottom of a rocket is to be stuffed with clay, and one diameter in height of the first preparation being introduced, the vacant space is to be filled with the following composition, and the mouth tied up. The pasteboard must be pierced into the preparation, with five holes, for the escape of the luminous rays, which represent a star.

Composition of fixed stars:—

	Ordinary.	Brighter.	Colored.
Nitre - - -	16	12	0
Sulphur - - -	4	6	6
Gunpowder meal -	4	12	16
Antimony - -	2	1	2

Lances are long rockets of small diameter, made with cartridge paper. Those which burn quickest should be the longest. They are charged by hand without any mould, with rods of different lengths, and are not strangled at the mouth, but merely stuffed with a quick match of tow. These lances form the figures of great decorations; they are fixed with sprigs upon large wooden frame works, representing temples, palaces, pagodas, &c. The whole are placed in communication by *conduits*, or small paper cartridges like the lances, but somewhat conical, that they may fit endwise into one another to any extent that may be desired. Each is furnished with a match thread fully 1½ inches long, at its two ends.

Composition for the *white lances:* nitre, 16; sulphur, 8; gunpowder, 4 or 3. For a *bluish-white:* nitre, 16; sulphur, 8; antimony, 4. For *blue lances:* nitre, 16; antimony, 8. For *yellow:* nitre, 16; gunpowder, 16; sulphur, 8; amber, 8. For *yellower* ones: nitre, 16; gunpowder, 16; sulphur, 4; colophony, 3; amber, 4. For *greenish* ones: nitre, 16; sulphur, 6; antimony, 6; verdigris, 6. For *pink lances:* nitre, 16; gunpowder, 3; lampblack, 1. Others less vivid are made with nitre, 16; colophony, 3; amber, 3; lycopodium, 3.

Cordage is represented in fire-works, by imbuing soft ropes with a mixture of nitre, 2; sulphur, 16; antimony, 1; resin of juniper, 1.

The Bengal flames rival the light of day. They consist of, nitre, 7; sulphur, 2; antimony, 1. This mixture is pressed strongly into earthen porringers, with some bits of quick match strewed over the surface. These flames have a fine theatrical effect for conflagrations.

Revolving suns, are wheels upon whose circumference rockets of different styles are fixed, and which communicates by *conduits*, so that one is lighted up in succession after another. The composition of their common fire is, for sizes below ¾ of an inch: gunpowder meal, 16; charcoal, not too fine, 3. For larger sizes: gunpowder, 20; charcoal, not too fine. 4. For *fiery radiations:* gunpowder, 16; yellow micaceous sand, 2 or 3. For *mixed radiations:* gunpowder, 16: pitcoal, 1; yellow sand, 1 or 2.

The *waving or double Catherine wheels*, are two suns turning about the same axis in opposite directions. The fusees are fixed obliquely and not tangentially to their peripheries. The wheel spokes are charged with a great number of fusees; two of the four wings revolve in the one direction, and the other two in the opposite; but always in a vertical plane.

The *girandoles*, *caprices*, *spirals*, and some others have on the contrary a horizontal rotation. The fire-worker may diversify their effects greatly by the arrangement and color of the jets of flame. Let us take for an example the *globe of light.* Imagine a large sphere turning freely upon its axis, along with a hollow hemisphere, which revolves also upon a vertical axis passing through its under pole. If the two pieces be covered with colored lances or cordage, a fixed luminous globe will be formed, but if horizontal fusees be added upon the hemisphere, and vertical fusees upon the sphere, the first will have a relative horizontal movement, the second a vertical movement, which being combined with the first, will cause it to describe a species of curve, whose effect will be an agreeable contrast with the regular movement of the hemisphere. Upon the surface of a revolving sun, smaller suns might be placed, to revolve like satellites round the primaries.

Ruggieri exhibited a luminous serpent pursuing with a rapid, winding pace a butterfly which flew continually before it. This extraordinary effect was produced in the following way. Upon the summits of an octagon he fixed eight equal wheels turning freely upon their axles, in the vertical plane of the octagon. An endless chain passed round their circumference, going from the interior to the exterior, covering the outside semi-circumference of the first, the inside of the second, and so in succession; whence arose the appearance of a great festooned circular line. The chain like that of a watch, carried upon a portion of its length a sort of scales pierced with holes for receiving colored lances, in order to represent a fiery serpent. At a little distance there was a butterfly constructed with white lances. The piece was kindled commonly by other fire-works, which seemed to end their play, by projecting the serpent from the bosom of the flames. The motion was communicated to the chain by one of the wheels, which received it like a clock from the action of a weight. This remarkably curious mechanism was called by the artists a *salamander.*

The rockets which rise into the air with a prodigious velocity, are among the most common, but not least interesting fire-works. When employed profusely they form those rich volleys of fire which are the crowning ornaments of a public fête. The cartridge is similar to that of the other jets, except in regard to its length, and the necessity of pasting it strongly, and planing it well; but it is charged in a different manner. As the sky-rockets must fly off with rapidity, their composition should be such as to kindle instantly throughout their length, and extricate a vast volume of elastic fluids. To effect this purpose, a small cylindric space is left vacant round the axis; that is, the central line is tubular. The fire-workers call this space the soul of the rocket (*ame de la fusée*). On account of its somewhat conical form, hollow rods, adjustable to different sizes of broaches or skewers, are required in packing the charge; which must be done while the cartridge is sustained by its outside mould, or copper cylinder. The composition of sky-rockets is as follows (see next page).

The cartridge being charged as above described, the *pot* must be adjusted to it, with the *garniture;* that is, the serpents, the crackers, the stars, the showers of fire, &c. The pot is a tub of pasteboard wider than the body of the rocket, and about one-third of its length. After being strangled at the bottom like the mouth of a phial, it is attached to the end of a fusee by means of twine and paste. These are afterward covered with paper. The garniture is introduced by the neck, and a paper plug is laid over it. The whole is enclosed within a tube of pasteboard terminating in a cone, which is firmly pasted to the pot. The quick-match is now finally inserted into the *soul* of the rocket. The rod attached to the end of the sky-rockets to direct their flight, is made of willow or any other light wood. M. Ruggieri replaced the rod by conical wings containing explosive materials, and thereby made them fly further and straighter.

The *garnitures* of the sky-rocket pots are the following:—

1. *Stars* are small, round, or cubic solids, made with one of the following compo-

When the bore is	¾ of an inch ;	¾ to 174 ;	1⅔ ;
Nitre - - -	16	16	16
Charcoal - -	7	8	9
Sulphur - -	4	4	4
Brilliant Fire.			
Nitre - - -	16	16	16
Charcoal - -	6	7	8
Sulphur - -	4	4	4
Fine steel filings -	3	4	5
Chinese Fire.			
Nitre - - -	16	16	16
Charcoal - -	4	5	6
Sulphur - -	3	3	4
Fine borings of cast-iron	3 coarser	4 mixed	5

sitions, and soaked in spirits. *White stars*, nitre, 16; sulphur, 8; gunpowder, 3. Others more vivid consist of nitre, 16; sulphur, 7; gunpowder 1.

Stars for golden showers, nitre, 16; sulphur, 10; charcoal, 4; gunpowder, 16; lampblack, 2. Others yellower are made with nitre, 16; sulphur, 8; charcoal, 2; lampblack, 2; gunpowder, 8.

The *serpents* are small fusees made with one or two playing cards; their bore being less than half an inch. The *lardons* are a little larger, and have three cards; the *vetilles* are smaller. Their composition is, nitre, 16; charcoal, not too fine, 2; gunpowder, 4; sulphur, 4; fine steel filings, 6.

The *petards* are cartridges filled with gunpowder and strangled.

The *saxons* are cartridges clayed at each end, charged with the brilliant turning fire, and perforated with one or two holes at the extremity of the same diameter.

The *cracker* is a round or square box of pasteboard, filled with granulated gunpowder, and hooped all round with twine.

Roman candles are fusees which throw out very bright stars in succession. With the composition (as under) imbued with spirits and gum-water, small cylindric masses are made, pierced with a hole in their centre. These bodies, when kindled and projected into the air, form the stars. There is first put into the cartridge a charge of fine gunpowder of the size of the star; above this charge a star is placed; then a charge of composition for the Roman candles.

The *stars*, when less than ¾ of an inch, consist of nitre, 16; sulphur, 7; gunpowder, 5. When larger, of nitre, 16; sulphur, 8; gunpowder, 8.

Roman candles, nitre, 16; charcoal, 6; sulphur, 3. When above ¾ of an inch, nitre, 16; charcoal, 8; sulphur, 6.

The *girandes*, or bouquets, are those beautiful pieces which usually conclude a firework exhibition; when a multitude of jets seem to emblazon the sky in every direction, and then fall in golden showers. This effect is produced by distributing a number of cases open at top, each containing 140 sky-rockets, communicating with one another by quick-match strings planted among them. The several cases communicate with each other by *conduits*, whereby they take fire simultaneously, and produce a volcanic display.

The water fire-works are prepared like the rest; but they must be floated either by wooden bowls, or by discs and hollow cartridges fitted to them.

Blue fire for lances may be made with nitre, 16; antimony, 8; very fine zinc filings, 4. Chinese paste for the stars of Roman candles, bombs, &c.:—Sulphur, 16; nitre, 4; gunpowder meal, 12; camphor, 1; linseed oil, 1; the mixture being moistened with spirits.

The *feu grêgois* of Ruggieri, the son:—Nitre, 4; sulphur, 2; naptha, 1. See PYROTECHNY and ROCKETS.

The red fire composition is made by mixing 40 parts of nitrate of strontia, 13 of flowers of sulphur, 5 of chlorate of potash, and 4 of sulphuret of antimony.

White fire is produced by igniting a mixture of 48 parts nitre; 13¼ sulphur; 7¼ sulphuret of antimony; or, 24 nitre, 7 sulphur, 2 realgar; or, 75 nitre, 24 sulphur, 1 charcoal; or, finally, 100 of gunpowder meal, and 25 of cast-iron fine borings.

The blue fire composition is 4 parts of gunpowder meal; 2 of nitre; sulphur and zinc, each 3 parts.

FISH-HOOKS (*Hamecons*, Fr.; *Fishangeln*, Germ.) are constructed with simple tools, but require great manual dexterity in the workmen. The iron wire of which they

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they are made should be of the best quality, smooth and sound. A bundle of such wire is cut in lengths, either by shears or by laying it down upon an angular wedge of hard steel fixed horizontally in a block or anvil, and striking off the proper lengths by the blows of a hammer. In fashioning the *barbs* of the hooks, the straight piece of wire is laid down in the groove of an iron block made on purpose, and is dexterously struck by the chisel in a slanting direction, across so much of the wire as may be deemed necessary. A sharp-pointed little wedge is thus formed, whose base graduates into the substance of the metal.

The end of the wire where the line is to be attached is now flattened or screw-tapped; the other end is sharp pointed, and the proper twisted curvature is given. The soft iron hooks are next case-hardened, to give them the steely stiffness and elasticity, by imbedding them in animal charcoal contained in an earthen or iron box; see CASE-HARDENING; after which they are brightened by heating and agitating them with bran, and finally tempered by exposure to a regulated temperature upon a hot iron plate. Hooks for salt-water fishing are frequently tinned, to prevent them wearing rapidly away in rust. See TIN PLATE.

FLAKE WHITE is the name sometimes given to pure white-lead.

FLAME (*Flamme*, Fr. and Germ.) is the combustion of an explosive mixture of an inflammable gas or vapor with air. That it is not, as many suppose, combustion merely at the exterior surface, is proved by plunging a fragment of burning phosphorus or sulphur into the centre of a large flame of alcohol. Either of these bodies will continue to burn there with its peculiar light; thus proving that oxygen is mixed with the whole of the burning vapor. If we mix good coal gas with as much atmospheric air as can convert all its carbon into carbonic acid, the mixture will explode with a feeble blue light; but if we mix the same gas with a small quantity of air, it will burn with a rich white flame. In the latter case the carbonaceous particles are precipitated, as Sir H. Davy first showed, in the interior of the flame, become incandescent, and constitute white light: for from the ignition of solid matter alone can the prismatic rays be emitted in that concentrated union. Towards the interior of the flame of a candle, a lamp, or a gas jet, where the air is scanty, there is a deposition of solid charcoal, which first by its ignition, and afterwards by its combustion, increases in a high degree the intensity of the light. If we hold a piece of fine wire gauze over a jet of coal gas close to the orifice, and if we then kindle the gas, it will burn above the wire with its natural brilliancy; but if we elevate the gauze progressively higher, so as to mix more and more air with it before it reaches the burning point, its flame will become fainter and less white. At a certain distance it becomes blue, like that of the above explosive mixture. Since the combustion of all the constituents is in this case direct and complete, the heat becomes greatest in proportion nearly as the light is diminished. If a few platina wires be held in that dim flame they will grow instantly white hot, and illuminate the apartment. On reversing the order of this experiment, by lowering progressively a flat piece of wire gauze from the summit towards the base of a gas flame, we shall find no charcoal deposited at its top, because plenty of air has been introduced there to convert all the carbon of the gas into carbonic acid, and therefore the apex is blue; but as we descend, more and more charcoal will appear upon the meshes. At the very bottom, indeed, where the atmospheric air impinges upon the gauze, the flame is again blue, and no charcoal can therefore be deposited.

The fact of the increase of the brilliancy and whiteness of flame by the developmen and ignition of solid matter in its bosom illustrates many curious phenomena. We can thus explain why olefiant gas affords the most vivid illumination of all the gases; because, being surcharged with charcoal, its hydrogen lets it go in the middle of the flame, as it does in an ignited porcelain tube, whereby its solid particles first get ignited to whiteness, and then burn away. When phosphorus is inflamed it always yields a pure white light, from the ignition of the solid particles of the snowy acid thus produced.

In the blowpipe the inner blue flame has the greatest heat, because there the combustion of the whole fatty vapor is complete. The feeble light of burning hydrogen, carbonic oxyde, and sulphur, may, upon the principles now expounded, be increased by simply placing in them a few particles of oxyde of zinc, slender filamants of amianthus, or fine platina wire. Upwards of twenty years ago I demonstrated, in my public lectures in Glasgow, that by narrowing the top of a long glass chimney over an argand flame either from oil or coal gas, the light could be doubled at the same cost of material. The very tall chimneys used by the Parisian lampists are very wasteful. I find that with a narrow chimney of half the length of theirs, I can have as good a light, and save 30 per cent. of the oil. Thus the light of a flame may be increased by diminishing its heat, or the intensity of its combustion; and conversely the heat of a flame may be increased by diminishing its light.

FLANNEL; a plain woollen stuff, of a rather open and slight fabric.

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FLAX. The general appellation of the fibrous produce used in the manufacture of linen threads, &c, of the plant *Linum usitatissimum*, which is cultivated, not for this produce only, but for that of its seed, employed in agriculture for feeding and fattening cattle, as well as in commerce for making the oil so well known as 'linseed oil."

This plant grows to the height of 2 or 3 feet, having a round and hollow stem, which divides into several branches, bearing blue flowers; these become the seed-pods of 10 cells, each of which contains one seed. As varieties, we distinguish the "spring" flax with short knotty stems, whose seed capsules at the period of maturity open with a perceptible sound; and the "close" flax, with longer, smoother stems, whose capsules give out the seed only when thrashed; the latter variety is the one most generally cultivated. Owing to the many improvements recently made in the various processes of the flax manufacture, all the operations for converting the raw plant to its ultimate useful and ornamental state have been greatly simplified and facilitated, and much attention has been paid to improving its cultivation, which has necessarily produced many changes in the formerly established modes of husbandry.

Flax may be grown upon a great variety of soils: the best is a sound, dry, deep loam, with a clay subsoil; this should be properly drained, as too much underground or surface water is alike injurious. It is necessary that the land should be brought to an exceedingly fine state by frequent ploughings and harrowings, commenced in the autumn previous to the sowing, which should take place toward the end of March, or beginning of April. From 2 to 2½ bushels of seed are required for one acre: the seed selected should be of a bright brown color, heavy, shining, and of an oily feel, avoiding such as have hard ends. Riga is the best for the greatest variety of soils, though Dutch is frequently used with great success. American does not generally suit, as it is apt to produce a coarse, branchy stem. The manner of sowing should be varied according to the purpose for which the crop is intended. When grain is the object of the grower, the sowing should be thin, as the plants then put out more branches, and thus yield more seed, but the fibrous produce becomes soft and meagre; the contrary is the case when the sowing is thick. Being one of the most tender plants of field cultivation, it requires very peculiar care in weeding, so as not to be injured by either the neglect or excess of this work, which should be done when the plants are about 3 inches high, that is, about a month after sowing. Guano and bone dust are suitable manures if farm dung is scarce. The following artificial manure, it has been said, will replace chemically the constituents of the plants produced from an acre of land, viz:—

Muriate of potash - - - -	30 lbs. ?
Common salt - - - - -	28 lbs.
Burned gypsum, powdered - - -	34 lbs.
Bone dust - - - - -	54 lbs.
Sulphate magnesia - - - -	56 lbs.

The average produce of seed is 12 bushels to the acre.

In regard to flax being considered a wasting crop for the land there are some observations to be made that may controvert that idea and establish one more sound in its place.

Assuming that the ashes of plants left after they are consumed by fire form a criterion of the quantity of nutritive matter they have extracted from the soil, there may at first sight appear much truth in the prevailing opinion as to the exhausting nature of the flax crop, since the ashes of this plant are 5$\frac{0}{0}$ of the whole, which is a large proportion. But as no ashes result from burning the pure fibre, which is solely the part that may not be reconsumed upon the land, it proves that the fertility of the soil is not injured by that production. The nutrition withdrawn by the other parts can be as easily replaced by this plant as by any other, $\frac{9}{10}$ths by the water alone in which the steeping is to be afterward carried on, and which should therefore be kept and employed as a liquid manure, to which must be added that more solid resulting from feeding cattle on the seed or oil cake, and from the ashes of the chaff, and thus a far greater part of the constituent of this plant is returned than of almost any other. Though the color of the flax is rather improved by letting the water run in a small stream through the steeping-pond during the operation, yet perhaps it may be a greater object to retain it for manure than to waste it for that purpose.

Whenever the flax is ripe, which is shown by the bottom of the stalk becoming yellow, and the leaves beginning to drop off, it must be immediately reaped by pulling it up by the roots. The seeds are still immature, fit merely for the oil press, and not for sowing. When the seed crop is the object, the plant must be suffered to acquire its full maturity; in which case the fibres are less fine and soft.

The flax is carried off the field in bundles to be rippled, or stripped of its seeds, which

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is done by drawing it by handfuls, through an iron comb with teeth eight inches long, fixed upright in a horizontal beam. When the seeds are more fully ripened, they may be separated by the thrashing mill.

The operations next performed upon the flax will be understood by attending to the structure of the stem. In it two principal parts are to be distinguished; the woody heart or boon, and the *harl* (covered outwardly with a fine cuticle), which encloses the former like a tube, consisting of parallel lines. In the natural state, the fibres of the harl are attached firmly, not only to the boon, but to each other, by means of a green or yellowish substance. The rough stems of the flax, after being stripped of their seeds, lose in moisture, by drying in warm air, from 55 to 65 per cent. of their weight; but somewhat less when they are quite ripe and woody. In this dry state they consist in 100 parts of from 20 to 23 per cent. of *harl*, and from 80 to 77 per cent. of boon. The latter is composed upon the average of 69 per cent. of a peculiar woody substance, 12 per cent. of a matter soluble in water, and 19 per cent. of a body not soluble in water, but in alkaline leys. The *harl* contains at a mean 58 per cent. of pure flaxen fibres, 25 parts soluble in water (apparently extractive and albumen), and 17 parts insoluble in water, being chiefly gluten. By treating the harl with either cold or hot water, the latter substance is dyed brown by the soluble matter, while the fibres retain their coherence to one another Alkaline leys, and also, though less readily, soap water, dissolve the gluten, which seems to be the cement of the textile fibres, and thus set them free.

The cohesion of the fibres in the rough harl is so considerable that by mechanical means, as by beating, rubbing, &c., a complete separation of them cannot be effected, unless with great loss of time and rupture of the filaments. This circumstance shows the necessity of having recourse to some chemical method of decomposing the gluten. The process employed with this view is a species of fermentation, to which the flax stalks are exposed; it is called *retting*, a corruption of rotting, since a certain degree of putrefaction takes place. The German term is *rusting*. This is the first important step in the preparation of flax. After the retting is completed, the boon of the stalks must be removed by the second operation called *breaking*, and other subordinate processes. The harl freed from the woody parts contains still a multitude of fibres, more or less coherent, or entangled, and of variable lengths, so as to be ill adapted for spinning. These are removed by the *heckle*, which separates the connected fibres into their finest filaments, removes those that are too short, and disentangles the longer ones.

I. *Of retting.*—The fermentation of this process may be either rendered rapid by steeping the flax in water, or slow by using merely the ordinary influence of the atmospheric damp, dews, and rain. Hence the distinction of water-retting and dew-retting. Both may also be combined.

Prior to being retted, the flax should be sorted according to the length and thickness of its stalks, and its state of maturity: the riper the plant, the longer must the retting last. The due length of the process is a point too little studied.

Water-retting.—When flax stalks are macerated in water, at a temperature not too low, fermentation soon begins, evinced in the dingy infusion, by disengagement of carbonic acid gas, and the production of vinegar. If the flax be taken out at the end of a few days, dried, and rubbed, the textile filaments are found to be easily separable from each other. By longer continuance of the steep, the water ceases to be acid, it becomes to a certain degree alkaline, from the production of ammonia, diffuses a fetid odor, from the disengagement of sulphureted hydrogen gas, along with the carbonic acid; the acetous fermentation being in fact now changed into the putrid. The filaments become yellowish brown, afterwards dark brown, and lose much of their tenacity, if the process be carried further.

When the operation is conducted with discernment, the water-retting may be completed by the acetous fermentation alone, as the putrefaction should never be suffered to proceed to any length; because when over-retted, flax is partially rotten, gets a bad color, and yields a large proportion of tow.

For water-retting, the flax must be bound up in sheaves, placed in layers over each other in the water, or sometimes upright, with the roots undermost. Straw may be put below to keep it from touching the ground, and boards may be laid upon the top, with weights to hold it immersed about a foot beneath the surface, especially when the fermentative gases make it buoyant. As soon as it sinks at the end of the fermentation, it must be inspected at least twice a day, and samples must be taken out to see that no over-retting ensues. A single day too long often injures the flax not a little. We may judge that the retting is sufficient when the harl separates easily from the boon by the fingers, when the boon breaks across without bending, and when several stalks knotted together sink to the bottom upon being thrown into the water. For this completion, a shorter or longer time is required according to the quality of the flax, the temperature, &c., so that the term may vary from five to fourteen days. It may be done either in running or in stagnant water. For the latter purpose, tanks five feet deep are dug in the ground. In stagnant water, the process is sooner finished, but it is more hazardous and gives a deeper stain to the fibres, than in a stream, which carries off much of the color. The best place for steeping flax is a pond with springs of water at its bottom; or a tank into which a rivulet of water can be occasionally admitted, while the foul water is let off. For every fresh quantity of flax, the pond should be emptied, and supplied with clear water. Water impregnated with iron stains flax a permanent color, and should therefore never be used. After retting, the flax should be taken out without delay, rinsed in clean water, and exposed in an airy situation to dry by the sun.

Rough rippled flax stalks, well seasoned before being retted, and dried afterward, show a loss of weight, amounting to 20 or 30 per cent., affecting both the boon and the harl. This loss is greater the finer the stems, and the longer the retting. The harl contains, besides the textile filaments, a certain portion of a glutinous cement; but nothing soluble in water. The destruction of the gluten can not be pushed to the last point by steeping, without doing an essential injury to the filaments.

Dew-retting.—The fetid and noxious exhalations which the water-retting diffuses over an extensive district of country, and the danger of over-retting in that way, especially with stagnant water, are far from recommending that process to general adoption. Dew-retting accomplishes the same purpose, by the agency of the air, dews, and rain, in a much more convenient, though far slower manner. The flax, with this view, should be spread out thin upon meadow or grass lands, but never upon the bare ground, and turned over, from time to time, till the stems, on being rubbed between the fingers, show that the harl and the boon are ready to part. The duration of dew-retting is, of course, very various, from two to six or eight weeks, as it depends upon the state of the weather; a moist air being favorable, and dry sunshine the reverse. The loss of weight by dew-retting is somewhat less than by water-retting; and the textile fibres are of a brighter color, softer and more delicate to the touch.

Mixed retting.—This may be fairly regarded as the preferable plan, the retting being begun in the water and finished in the air. The flax should be taken out of the steep whenever the acetous fermentation is complete, before the putrid begins, and exposed, for two or three weeks, on the grass.

Within the last two years, the hazardous and tedious process above described has been attempted to be superseded by steeping the flax plant in vats of water artificially heated to 70° Fahr., whereby the effects are produced in sixty or seventy hours. Drying by fire in kilns is pernicious alike to the seed or fibrous produce; as in the former it dries up too soon the nutritious particles that would be absorbed by the seed from its pod or outer covering, and in the latter impairs the rich and oily property of the flax. The following is a description of an establishment for the prosecution of Mr. Schenck's process, situated at Newport river, county Mayo. The tenements containing the vats and drying shelves are simple wooden sheds of cheap construction. In one end of the building are four vats set parallel to each other the length of the house; they are made of inch deal in the form of a parallelogram, fifty feet long, six broad, and four deep. There are false bottoms perforated with holes; underneath these are introduced the steam-pipes, crossing the vats, and having stop-cocks at their entrance, by which the steam can be let on from the main pipe as required. The steam is generated in a small boiler, which also serves to turn two *hydro-extractors*, a patent apparatus used to drive off a portion of the water with which the flax is saturated, on being taken from the vats. The flax is packed into the empty vats, on the butt ends, in a half sloping position, precisely as in the case of a steep pool, only one layer being the depth. The water is then let in, and a frame fastened over the top of the flax, answering the end of stones and straw or soda in the steeping pools, for prevention of the rising of the flax in course of fermentation. This process is now renounced.

The steam is then let into the pipes by turning the stop-cocks, and the water is some eighteen or twenty hours in becoming heated to the required point, 85° or 90°. The fermentation then commences, and no further steam is required, the action going on until the flax is thoroughly retted, which is in forty hours afterward, being sixty from the time of the admission of the water. At the end of the sixty hours, the flax is taken out the water allowed to run off, and the vat permitted to cool. The same process is then repeated with fresh water and fresh flax. When taken from the water, the flax is packed in the hydro-extractor, which is a round vessel of iron made to revolve by steam power with great velocity, the water being driven out of the flax on the principle of the centrifugal force. Thirty beets or small handfuls are placed in this machine at a time, and about 20 lbs. of water are extracted in from three to five minutes. A few hours suffice for the contents of a vat, each vat containing 2 tons of flax straw. The hydro-extractor only separates a portion of the water; the flax now remains to be

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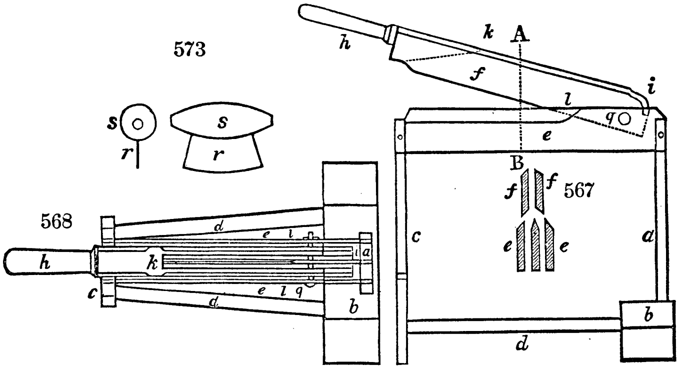
thoroughly dried. In summer, or indeed, for six months in the year, this can be accomplished, as usual, by spreading upon grass land in the open air. During winter, however, it is necessary to procure other means of drying. A shed has therefore been erected, communicating by doors with the vat house, filled with ranges of shelves, composed simply of railings of lathwood in five or six tiers. The flax is spread lightly along these shelves by women, and the house is heated by steam-pipes. This house is capable of drying the full of one vat per diem. The flax, when dried, is made up in beets or handfuls, of a size suited for feeding into the breaking rollers of the mill.

2. *The breaking* is performed by an instrument called a brake. In order to give the wood or boon such a degree of brittleness as to make it part readily from the harl, whereby the execution of this process is rendered easy, the flax should be well dried in the sun, or what is more suitable to the late period of the year, in a stove. Such is often attached to the bakers' ovens in Germany, and other flax-growing countries. The drying temperature should never exceed 120° F., for a higher heat makes it brittle, easy to tear, and apt to run into tow. Before subjecting the flax to the brake, the stems should be equalized and laid parallel by the hand, and the entangled portions should be straightened with a coarse heckle. The brake has one general construction, and consists of two principal parts, the frame or case, and the sword or beater. In the simplest brakes, the frame *e*, *fig.* 566, is a piece of wood cleft lengthwise in the middle, supported by the legs *a* and *c*. The sword *f*, also of hard wood, is formed with an edge beneath, and turns round the centre of motion at *q*, when seized by the handle *h*, and moved up and down. As it descends, the sword enters the cleft of the frame, and breaks the flax stalks laid transversely upon it, scattering the boon in fragments.



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But those hand brakes are more convenient which are provided with a double cleft, or triple row of oblong teeth, with a double sword. This construction will be understood by inspecting *figs.* 566, 567, 568. *Fig.* 566 is the section of that side at which the operative sits; *fig.* 567 is a section in the line A B, of *fig.* 566; and *fig.* 568, the ground plan. The whole machine is made of hard wood, commonly red beech. Two planks, *a* and *c*, form the legs of the implement. *a* is mortised in a heavy block, to give the brake a solid bearing; two stretchers *d* bind *a* and *c* firmly together. The frame *e* consists of three thin boards, which are placed edgewise, and have their ends secured in *a* and *c*. The sword *f* is a piece of wood, so chamfered from *i* to *k*, that it appears forklike, and embraces the middle piece of the frame; its centre of motion is the wooden pin *q*; in front is the handle *h*, which the operative seizes with the right hand. Both the lathes of the frame and those of the sword are sharpened, from *l* to the front end, as is best shown in *fig.* 567; but the edges must not be too sharp, for fear of injuring the flax; and, for the same reason, the sword should not sink too far between the lathes of the frame. Such hand-brakes are laborious in use, and often tear the harl into tow. The operative, usually a female, in working the brake, seizes with her left hand a bundle of flax, lays it transversely across the frame, and strikes it smartly with repeated blows of the sword, pushing forward continually new portions of the flax into the machine. She begins with the roots, turns next round the tips, then goes on through the length of the stalks. Flax is frequently exposed twice to the brake, with a stove-drying between the two applications.

The brake machines afford a far preferable means of cleaning flax than the above hand tools. The essential part of such a machine consists in several deeply fluted rollers of wood or iron, whose teeth work into each other, and while they stretch out the flaxen stalks between them, they break the wood or boon, without doing that violence to the harl which hand mechanisms are apt to do. The following may be regarded as one of the best constructions hitherto contrived for breaking flax. *Fig.* 569 is a view of the right side of this machine. *Fig.* 570, the view from behind, where the broken flax issues from between the rollers. The frame is formed by the two side pillars or walls *a*, *a*, which are mortised into the bottom *b*, *b*; and are firmly fixed to it by braces. Two transverse rods *d*, *d*, secure the base, two others *d′ d′*, the sides. In each of these a lateral arm *e*, is mortised in an oblique direction; a cross bar *f*, unites both arms. *Fig.* 571 shows the inside of the left side of the frame, with the subsidiary parts. The three rollers, *g*, *i*, *k*, may be made of red beech, with iron gudgeons, and fluted in their length, each of the flutes being $\frac{5}{12}$ths of an inch broad, and $\frac{4}{12}$ths deep. The large roller *g*, bears upon the right side, a handle *h*, which on being turned, sets the whole train in motion. The side partitions *a*, *a*, are furnished with brasses in whose round holes, *l*, *g*, *fig.* 571, the gudgeons *g* work. For the extremities of the two smaller rollers, there are at *a* and *e* slots in brasses, as may be seen in *fig.* 569. Within the partition *a*, there are movable brasses *l*, for the pivots of *i* and *k*, shown in *fig.* 571. Each brass slides in a groove, between two ledges. A strong cord made fast at *m* to the partition *a*, runs over the brass of *i*, next over that of *k*, then descends perpendicularly, and passes over the cross bar *n*, *figs.* 569 and 570. This construction being repeated at both ends of the rollers, the rod *n* binds both cords. Against the cross bar *d′* of the frame, a lever *o* is sustained, which lies upon the rod *n*, and carries a weight *p*. The farther or nearer this weight hangs toward the end of the lever, it stretches the cord more or less, and presses by means of the brasses *l*, the rollers *i*, *k*, toward the main roller *g*. A table *q*, serves for spreading out the flax to be broken, and a second one *r*, for the reception of the stalks at their issuing from between the rollers. Both tables

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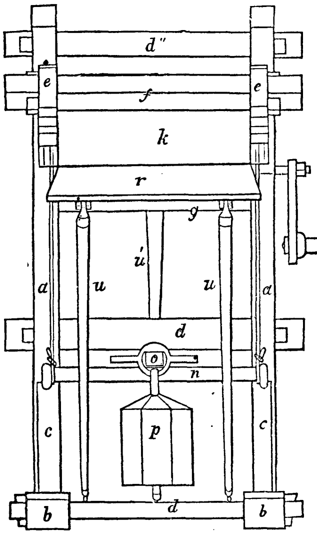

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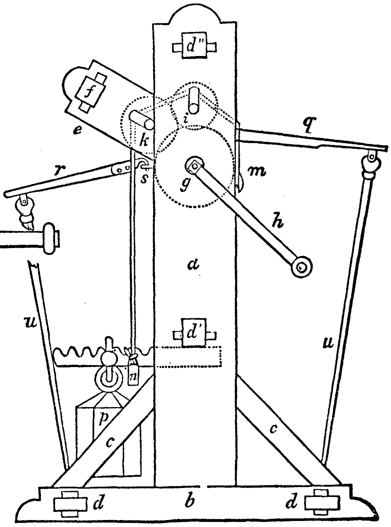

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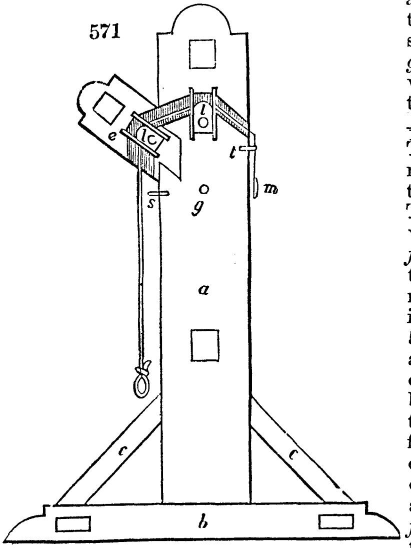

hang by means of iron hooks to rings of the frame *s*, *t*, *figs.* 569 and 571, and are supported by the movable legs *u*, *u*, *u*, *figs.* 569 and 570. In using the machine the operative lays an evenly spread handful of flax upon the table *q*, introduces their root ends with his left hand between the rollers *g* and *i*, and turns round the handle *h*, with the right. The stems are first broken betwixt *g* and *i*, then between *g* and *k*, and come out upon the table *r*. The handle is moved alternately forward and backward, in order that the flax may be rolled alternately in the same directions, and be more perfectly broken. The boon falls down in very small pieces, and the harl remains expanded in parallel bands. This should be drawn over the points of a heckle, then laid for a couple of days in a cellar to absorb some moisture, and afterward worked once more through the machine, whereby the flax acquires a peculiar softness.

The advantages of this brake machine are chiefly the following :—

It takes up little room, and from its simplicity is easily and cheaply constructed; it requires no more power to work, than the ordinary hand-brake; it tears none of the filaments, and grinds nothing except the boon, in consequence of the flutings of the rollers going much less deep into each other, than the sword of the hand-brake; it prevents all entanglements of the flax, whence in the subsequent heckling the quantity of short fibres or tow is diminished; and it accomplishes the cleaning of even the shortest flax, which cannot be well done by hand machines.

The comminution of the boon of the stems, which is the object of the breaking process, can however be performed by thrashing or beating, although in this way the separation of the woody matter from the textile fibres is much less completely effected. It is the practice in Great Britain, instead of breaking, to employ a water-driven wooden mallet, between which and a smooth stone the flax is laid. In that part of Belgium where the preparation of flax has been studied, the brake is not used, but beating by means of the *Bott-hammer*, to the great improvement, it is said, of the flax. The *Bott-hammer*, *fig.* 572, is a wooden block, having on its under face channels or flutings, 5 or 6 lines deep, and it is fixed to a long bent helve or handle. In using it, a bundle of the dried flax stalks is spread evenly upon the floor, then powerfully beaten with the hammer, first at the roots, next at the points, and lastly in the middle. When the upper surface has been well beat in this way, it is turned over, that the under surface may get its turn. The flax is then removed, and well shaken to free it from the boon.

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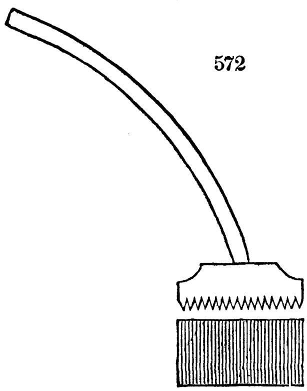

By the brake or the hammer the whole wood is never separated from the textile fibres, but a certain quantity of chaffy stuff adheres to them, which is removed by another operation. This consists either in rubbing or shaking. The rubbing is much practised in Westphalia, and the neighboring districts. In this process, the operative lays the rubbing apron on a piece of dressed leather, one foot square, upon her knee; then seizes a bundle of flax in the middle with her left hand, and scrapes it strongly with the *Ribbeknife* held in her right, *fig.* 573. This tool, which consists of a wooden handle *s*, and a thin iron blade *r*, with a blunt and somewhat bent edge, acts admirably in cleaning and also in parting the filaments, without causing needless waste in flax previously well broken.

The winnowing, which has the very same object as the rubbing, is, however, much more generally adopted than the latter. Two distinct pieces of apparatus belong to it, namely, the *swing-stock* and the *swing-knife*. The first consists of an upright board with a groove in its side, into which a handful of flax is so placed that it hangs down over half the surface of the board. While the left hand holds the flax fast above, the right carries the swing-knife, a sabre-shaped piece of wood from 1½ to 2 feet long, planed to an edge on the convex side, and provided with a handle. With this knife the flax is struck parallel to the board, with perpendicular blows, so as to scrape off its woody asperities. The breadth of the swing-knife is an important circumstance; when too narrow it easily causes the flax to twist round it, and thereby tears away a portion of the fibres. When 8 or 10 inches broad, it is found to act best. Knives made of iron will not answer, for they injure the filaments.

Figs. 574, 575 show the best construction of the swing-stock. The board *a* has for its base a heavy block of wood *b*, upon which two upright pins *e e*, are fixed. The band *f*, which is stretched between the pins, serves to guide the swing-knife in its movements, and prevent the operative from wounding his feet. The under edge of the groove *c*, upon which the flax comes to be laid, is cut obliquely and rounded off (see *d*

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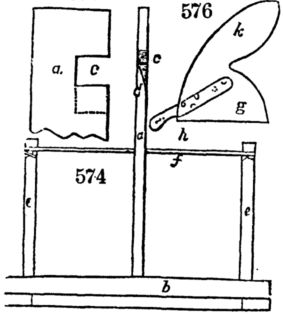
In ***fig.*** **574); thus we perceive that the swing-knife can never strike against that edge, so as to injure the flax.**

Fig. 576 exhibits the form of a very convenient implement which is employed in Belgium instead of the swing-knife. It is a sort of wooden hatchet, which is not above two lines thick, and at the edge *g h* is reduced to the thickness of the back of a knife. The fly *k* gives force to the blow, and preserves the tool in an upright position. The short flat-pressed helve *i* is glued to that side of the leaf which in working is turned from the swing-stock; and is, moreover, fastened with a wooden pin.

575 576 574



The rubbing and swinging throw off the coarsest sort of tow, by separating and shaking out the shortest fibres and those that happen to get torn. That tow is used for the inferior qualities of sacking, being mixed with many woody fibres.

We may in general estimate that 100 pounds of the stalks of retted flax, taken in the dry state, afford from 45 to 48 pounds of broken flax, of which, in the swinging or scutching, about 24 pounds of flax, with 9 or 10 pounds of scutch tow are obtained. The rest is boon-waste. The breaking of 100 pounds of stalks requires, in the ordinary routine of a double process by hand, about 20 hours; and with the above described machine, from 17 to 18 hours. To scutch 100 pounds of broken flax clean, 130 hours of labor are required by the German swinging method.

Mr. Bundy obtained a patent in 1819, for certain machinery for breaking and preparing flax, which merits description here. *Fig.* 577, A A A A, is the frame, made either of wood or metal, which supports the two conical rollers B and C. These revolve independently of each other in proper brass bearings. A third conical roller D is similarly supported under the top piece E of the machine. All these rollers are *frusta* of cones, made of cast iron. Whatever form of tooth be adopted, they must be so shaped and disposed with regard to each other as to have considerable play between them, in order to admit the quantity of flax stem which is intended to be broken and prepared. The upper piece E of the machine which carries the upper conical roller D, is fixed or attached to the main frame A A A A by strong hinges or any other moveable joint at G, and rods of iron or other sufficiently strong material; H H is attached at its upper end by a joint to the top piece E, through a hole near I, and is fixed at its lower end by another joint K to the treadle or lever K L, which turns upon the joint or hinges M. A spring or weight (but the former is preferable for many reasons) is applied to the machine in such manner, that its action will always keep the upper piece E, and consequently the upper roller D, in an elevated or raised position above the rollers B and C, when the machine is not in action; and of course the end L of the treadle will also be raised, which admits of the flax to be worked being introduced between the rollers, viz., over the two lower rollers B, C, and under the upper roller D; such a spring may be applied in a variety of ways, as between the top piece E, and the top or platform of the machine at N; or it

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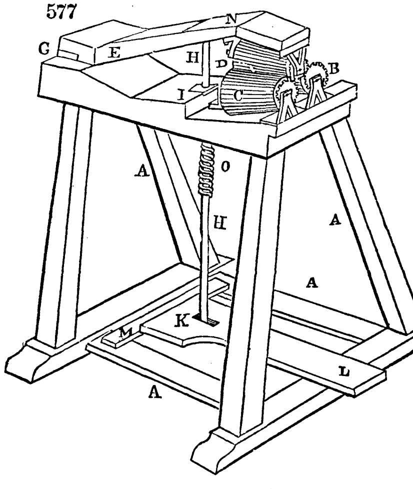

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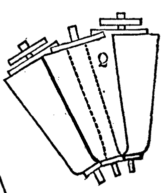

rollers B, C, and under the upper roller D; such a spring may be applied in a variety of ways, as between the top piece E, and the top or platform of the machine at N; or it may be a strong spiral wire spring, having its upper end fastened to the platform while its lower extremity is fixed to the rod H H, round which it coils as shown at O, or it may be placed under the end L of the treadle; but in every case its strength must be no more than will be just sufficient to raise the upper roller D about two inches from the lower rollers, otherwise it will occasion unnecessary fatigue to the person working the machine.

The manner of using it is as follows: the upper and lower rollers being separated as aforesaid, a small handful of dried flax or hemp stems is to be introduced between them, and held extended by the two hands, while the rollers are brought together by the pressure of the foot upon the treadle L. This pressure being continued, the flax or hemp is to be drawn backwards and forwards by the hands between the rollers, in a direction at right angles to their axes, and eventually withdrawn by pulling with one hand only. The foot is now to be removed until the flax or hemp is again replaced, and each end is this way to be drawn several times through the machine, until such ends are respectively finished.

By a succession of these operations, using the pressure of the foot upon L, each time that the flax or hemp is introduced between the rollers, and regulating such pressure according to the progress of the work, the flax or hemp will soon be sufficiently worked and the fibre brought into a clean and divided state fit for bleaching; or if it be required to spin it in the yellow state, it may be made sufficiently fine by a longer continuation of the same process, particularly if worked between the smaller ends of the rollers.

Indeed, the operation may be commenced and continued for some time, with the larger part of the rollers, and finished with their smaller ends; and, in this point of view, the invention of conical rollers will be found both convenient and useful; for as the flutes, grooves, or teeth vary in their distance from each other at all points between the large and small ends, so it becomes almost impossible for the workman to draw the flax or hemp through such rollers in the same track; and thus the breaking of the boon must be much more irregular, and the fibre will be much more effectually cleansed than it can be by the flutes, grooves, or teeth of cylinders, or other such contrivances formerly employed; because they would probably fall frequently upon the same points of the fibres. If it is intended that the flax shall be bleached before it is spun, then the second part of Mr. Bundy's invention may be had recourse to, which consists in moving certain trays or cradles in the water, or other fluid used for bleaching the flax or hemp in the manner following, viz.: The flax or hemp, after having been broken and worked in the machine, should be divided into smaller quantities of about one ounce each, and these should be tied loosely in the middle with a string, and in this state laid in the trays or cradles, and then be soaked in cold soft water for a day or two, when each parcel should be worked separately, while wet, through a machine, precisely similar to that already described, except only that the rollers should be cylindrical, and made entirely of wood with metal axles, and the teeth, which will be parallel, should be similar in form to those shown in section at Q, *fig.* 578. Such operation will loosen the gluten and colouring matter, for the rinsing and wringing which must follow. The flax must then be again disposed in a flat and smooth manner, in such trays or cradles, and once more set to soak in sufficient soft water to cover it, in which a small quantity of soap, in the proportion of about seven pounds of soap to each hundred weight of flax, has been previously dissolved, and in this state it should remain for two or three days longer, and then be finally worked through the machine, rinsed with clear water, and wrung: which will render it sufficiently white for most purposes.

Can flax be prepared without retting?—The waste of time and labour in the steeping of flax; the dyeing of the fibres consequent thereon, which must be undone by bleaching; the danger of injuring the staple by the action of putrescent water; and, lastly, the diminished value of flax which is much water-retted, are all circumstances which have of late years suggested the propriety of superseding that process entirely by mechanical operations. It was long hoped, that by the employment of breaking machines, the flax merely dried could be freed from its woody particles, while the textile filaments might be sufficiently separated by a subsequent heckling. Experience has, however, proved the contrary. The machines, which consisted for the most part of fluted rollers of iron or wood, though expensive, might have been expected to separate the ligneous matter from the fibres; but, in the further working of the flax no advantage was gained over the water-retting process.

1. Unretted flax requires a considerably longer time for breaking than retted, under the employment of the same manipulations.

2. Unretted stalks deliver in the breaking and heckling a somewhat greater product than the same weight of flax which has been retted; but there is no real advantage in

this, as the greater weight of the unretted flax consists in the remainder of ligneous or glutinous matter, which being foreign to the real fibre, must be eventually removed. In the bleaching process, the water and the alkaline lyes take away that matter, so that the weight of the bleached fibre is not greater from the unretted than the retted flax.

3. The parting of the fibres in the unretted stalks is imperfectly effected by the heckling; the flax either remains coarser as compared with the retted article, and affords a coarser thread, or if it be made to receive greater attenuation by a long-continued heckling, it yields incomparably more torn filaments and tow.

4. The yarn of unretted flax feels harder, less glossy, and rougher; and, on account of these qualities, turns out worse in the weaving than the retted flax. Nor is the yarn of unretted flax, whether unbleached or bleached, in any degree stouter than the yarn of the retted flax.

5. Fabrics of unretted flax require for complete bleaching about a sixth less time and materials than those of the retted. This is the sole advantage, but it is more than counterbalanced by the other drawbacks above specified.

The foregoing operations having brought the flax into the ordinary fibrous merchantable state, suitable for the spinner, it now remains to pass through the following processes, by which it is manufactured into yarns for sale or use, viz., 1st, heckling, 2nd, preparing, 3rd, spinning, 4th, reeling, 5th, drying, and 6th, making up.

6. *Heckling.* The operation of heckling has for its objects, 1st, that of combing or straightening the filaments entangled as coming from the scutching. 2d, that of splitting them, with a view of lessening and equalizing their size. In accomplishing these objects the material is unavoidably divided into two portions. The long and straight fibres constituting the first, called "line," and the short, broken, and confused of the second, "tow." Both the line and tow are capable of being spun, but the line is much the more valuable, being used for the better descriptions of yarns, &c., with greater facility than the tow for the inferior. The aim, therefore, of good heckling is to produce the larger proportion of line from a given quantity of flax, the attainment of which leaves much scope for care and judgment, whether the older method of heckling by hand or the more recent by machine is adopted. In hand heckling the instruments are a comb-fashioned tool, called the *heckle* or *hackle;* a surface studded more or less thickly with metal points, called heckle teeth; over which the flax is drawn in such a way that the above three required operations may be properly accomplished.

The heckles ordinarily used for hand heckling in this country are in the form of rectangular parallelograms, presenting a line of 7 inches towards the worker and 4 to 5 inches deep. The first tool employed is called the "ruffer," the pins of which are about ¼ inch square at their base, and 7 inches long, and brought to a fine point; the second is the "common 8," which is always used after the "ruffer;" then the "fine 8," the "10," the "12," the "18." The pins of all these tools are similarly placed to those of the ruffer, but are somewhat shorter in length and are more slender as the tools increase in fineness. In all these tools the pins are held in wooden stocks of about ¾ inch in thickness and covered with sheet tin. This sheet tin, through which the pins are driven, helps to support them and prevent the wood from splitting. These tin covered stocks are only of a size necessary for the extent of pins employed, and are themselves screwed to other larger pieces of board, a little broader and some inches longer than themselves, and by which they are ultimately fixed to the heckler's bench, inclining somewhat backward with their points from the worker, and a sloping board behind to prevent the flax entering too much in the pins, thus:

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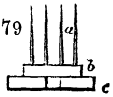

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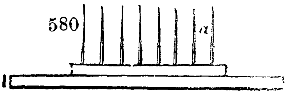
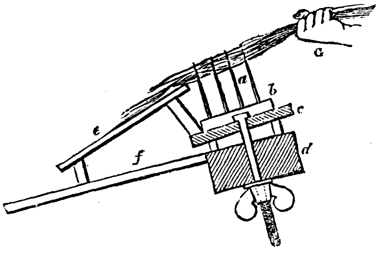
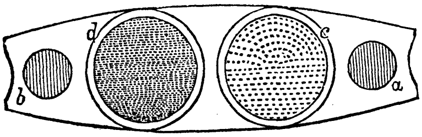




581

Fig. 579. end view of a heckle; *fig.* 580. front view of heckle; *fig.* 581. heckle, &c. fixed up for working. *a* pins; *b* tin covered stock; *c* foundation board; *d* beam of table or bench; *e* back board; *f* table to receive the tow, &c.; *g* hand of workman. Such is the form of heckle used in England, and also the manner they are, of whatever description, fixed for work.

582



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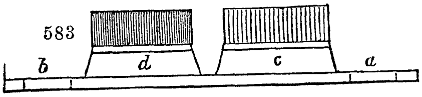


In Germany the common construction of the heckle is the following; (see *fig.* 582.) *Fig.* 582. is the ground plan, and *fig.* 583. is the section. Upon an oblong plank *a b*, two circular or square blocks of wood *c* and *d* are fixed, in which the heckle teeth stand upright. To give these a firmer hold they are stuck into holes in a brass or iron plate, with which the upper surface of *c* and *d* is covered. Both heckles may be either associated upon one board or separated; and of different finenesses; that is, the teeth of the one may be thinner, and stand closer together; because the complete preparation of the flax requires for its proper treatment, a two-fold heckling; one upon the coarse, and one upon the fine heckle; nay, sometimes 3 or 4 heckles are employed of progressive fineness. The heckle teeth are usually made of iron, occasionally of steel, and from 1 to 2 inches long. Their points must be very sharp and smooth, all at an equal level, and must all graduate very evenly into a cylindrical stem, like that of a sewing needle, without any irregularity. The face of the heckle block must be uniformly beset with teeth, which is done by different arrangements, some persons setting them in a circle, and others in parallel rows. The coarse heckle is furnished with teeth about one-tenth of an inch thick, one and a quarter of an inch long, and tapering from the middle into a very fine point. In the centre of the circular heckle is a tooth planted; the rest are regularly set in 12 similar concentric circles, of which the outermost is 5¾ inches in diameter. The fine heckles contain no fewer than 1,109 teeth. Instead of making the points of the teeth round, it is better to make them quadrangular, in a rhombus form, in which case the edges serve to separate or dissect the fibres.

The operation of manual heckling is simple in principle, although it requires much experience to acquire dexterity.

The workman having first divided the flax into handfuls or stricks, of which there are 300 to 400 to the cwt., proceeds to grasp one as flatly spread as possible between his forefinger and thumb, by about its middle, and wind the top end round his hand in order the better to prevent the slipping of the fibres; he then begins by a circular swing of his arm to lash the root end into the heckle, taking care to commence as near the extremity as possible, now and then collecting the fibres by holding his left hand in front of the tool, turning the strick from time to time; he thus gradually works up as near as possible to his right hand, when he seizes the ruffed part of the strick and holds it in the same manner as at first, and proceeds by similar treatment to "ruff" the top end; when this is finished the "ruffed" work is taken to the tool called a "common 8," the pins of which are much closer placed than those of the ruffer, and are only 4 or 5 inches long. This "8" is always used after the ruffer, but from it the work can be taken to any of the finer tools, viz. 8, 10, 12, and sometimes 18. It is usual and better to dress both ends over each tool before taking the work to the next. The pins of all these tools are 4 inches long, in order, as was supposed, to have sufficient spring. The flax is not lashed into them as into the ruffers, neither are the ends required to be wound round the hand. But the root end of the flax is always the one to be first worked, and the heckling begun at nearly the extremity of the strick, which on being drawn through the heckle is received by the left hand of the workman, and by it carried back and laid upon the back board and over the point of the pins, for the angle of inclination of the heckles and a slight lowering of the right hand causes it to enter sufficiently on being drawn forward. As it is impossible to ruff or dress entirely up to the hand, when the hold is changed in either operation, there must of necessity be left a certain space to be repassed through the tools; this is called the "shift," but the less length that is required for this purpose the better for the yield of lime. The numerous long fibres that slip from the strick in ruffing must be collected and drawn from the mass of tow attached to them, when they can be relaid in the strick, or kept to be dressed separately under the name of "shorts," and from time to time the short fibres or tow sticking to the teeth of the finer tools are removed. Whenever one half of the length of the strake of flax is heckled, it is turned round to heckle the other half. This process is repeated upon each heckle. From 100 pounds of well-cleaned flax, about 45 or 50 pounds of heckled line may be obtained by the hand labour of 12 hours; the rest being tow, with a small waste in bony particles of dust. The process is continued, till by careful handling little more tow is formed.

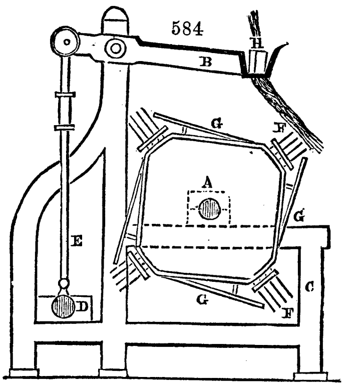
To aid the heckle in splitting the filaments, three methods have been had recourse to; beating, brushing, and boiling with soap-water, or an alkaline lye.

Beating flax either after it is completely heckled, or between the first and second heckling, is practised in Bohemia and Silesia. Each heckled tress of flax is folded in the middle, twisted once round, its ends being wound about with flaxen threads; and this head, as it is called, is then beat by a wooden mallet upon a block and repeatedly turned round till it has become hot. It is next loosened out, and rubbed well between the hands. The brushing is no less a very proper operation for parting the flax into fine filaments, softening and strengthening it without risk of tearing the fibres. This process requires in tools, merely a stiff brush made of swines' bristles, and a smooth board, 3 feet long and 1 foot broad, in which a wooden pin is made fast. The end of the flax is twisted two or three times round this pin to hold it, and then brushed through its whole length. Well heckled flax suffers no loss in this operation; unheckled, only a little tow; which is of no consequence, as the waste is thereby diminished in the following process. A cylindrical brush turned by machinery might be employed here to advantage. These have been tried in establishments for machine spinning, but not found advantageous.

The boiling of flax with potash lye alone, or with lye and soap, dissolves that portion of the glutinous cement which had resisted the retting, completes the separation of the fibres, and was therefore supposed a good practical means of improving flax. When it is performed upon the heckled fibres, a supplementary brushing is requisite to free it from the dust, soapy particles, &c., but this also is now abandoned.

Machine heckling.—As intimated above, the object of all heckling was that of producing a good yield of line with tows of good quality that is to say, free from broken unsplit fibres, lumps and knots: the care and attention to do this, together with the expense and uncertain results of the individual skill of workmen, urged manufacturers some time since to attempt the establishment of machines for dressing flax mechanically. Therefore many contrivances have been made with this view, but it was long doubted whether any of them made such good work with so little loss as hand labour. In heckling by the hand, it was supposed the operative would feel at once the degree of resistance, and be able to accommodate the traction to it, or throw the flax more or less deeply among the teeth, according to circumstances, and draw it with suitable force and velocity. For a considerable period these ideas, or rather prejudices as they may now be called, seemed to be confirmed: for the earlier attempts to supersede hand heckling, like those in many other undertakings, though partially favourable, were upon the whole somewhat discouraging: in attaining one point desired another one was lost, for too much still depended upon the care and attention, if not upon the actual skill, of the attendants. Therefore, a review of those machines that really came into operation, to a more or less limited extent, as well as a slight mention of some of those patented, but never publicly shown, may not be useless as a lesson for preventing a repetition of things already known, as well also for illustrating the steps by which these first prejudices have been gradually overcome. The first heckling machine invented, or at least published, was called the "Peter," and was intended to imitate as closely as possible the movements of the hand heckles. In commencing the work, the flax was first divided into small convenient portions or handfuls, of about 4 ounces each, called "stricks," and which, before being taken to the machine, were slightly straightened and dressed over the ordinary hand "ruffer." Each of these stricks was then placed between a pair of short iron bars, one of these bars having an indentation along its middle, and the other a corresponding projection; thus, when tightened together by screws 4½ inches apart (such a length being equal to a hand-heckler's grasp), the flax was firmly held while exposed to the action of the heckles, (this pair of bars with screws being called a "holder"). This holder was then suspended from movable levers over a truncated rectangular cylinder, upon the truncated angles of which were fixed, at a certain angle, heckles similar to those used in the manual operation. The levers supporting the holders received from a crank a short up and down motion, so timed in their oscillations as to strike the holder nearly against the points of the pins at the time they were passing under, coming thus as nearly as possible to the effect of a man striking in and drawing through the heckles, with the exception that the flax remained nearly stationary, and the heckle was drawn through it by the rotation of the cylinder; such machine carried two holders. The tow made and collected in the heckles, was seized and taken off by boys stationed for that purpose, while another at the ring of a bell took out and changed the sides of the stricks to be presented to the action of the heckles, and subsequently withdrew them from the first machine to another similar but with finer heckles, and thus continued till the root end (always the first to be operated upon) was dressed to the desired degree of fineness, when they would be taken to a table where another set of boys, previously to removing the first holder, put on a second to the already heckled part, leaving a short length of 2½ or 3 inches to be reheckled. This operation is termed shifting, and the space left the "shift," and is thus performed and so called at the present day; the only change in the holder now in use being, that one screw is used for two stricks instead of two screws for one strick. *Fig.* 584. will more clearly show the construction of this machine.

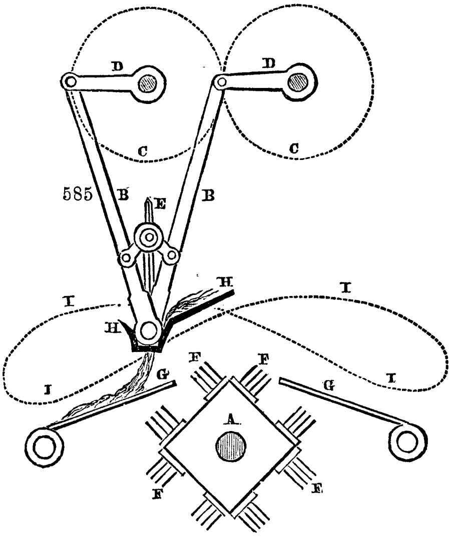
584



A square truncated cylinder carrying the heckles; B oscillating arm or lever for supporting the holder; C C C framing; D crank and shaft; E connecting rod from crank to oscillating arm; F, F, F, F heckles; G G G G back board; H holder. The first motion was given by pulleys on the shaft D, which revolved 4 times to 1 of the heckle cylinder, by the intervention of suitable wheels. The worm and wheels for the bell motion were attached in the usual manner to the shaft of the cylinder.

Machines of this construction continued in rather limited use without any change or competition till about the year 1825, when a patent was taken for a machine known as the pendulum machine. The flax in the holder being suspended and swung backwards and forwards while the heckle remained fixed, thus the flax was heckled, stroke for stroke, on each of its sides. The boys as in the last described, snatching off the tow as it was formed, and at certain times, that is at each rise of the pendulum, for it had a rising and falling motion to imitate the hand workers in commencing at the extreme end of the flax, passing the holder from one recess to another of the pendulous table, so as to arrive at the progressively finer tools when ranged along the machine, but sometimes the different tools were fixed upon the angles of a square cylinder that presented a finer range, the whole length of the machine, by turning up a new angle at each rise of the pendulum, when the labour of the boys was simply to put in the tow and take out from it the flax. The adjoining diagram, (*fig.* 585.) without entering on any details of a machine that was so little used, will make the theory of its action quite clear.

585

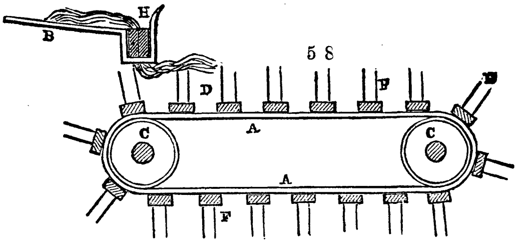


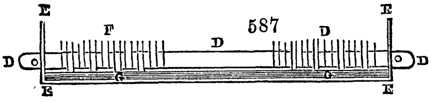
A heckle bench sometimes revolving so as to present different degrees of heckles at its various angles, sometimes stationary with the gradations of heckles upon its length; B B, pendulum arms; C C, equal wheels working into each other; D D, crank arms; E radial slide-bars to preserve the holder table vertical; H, holder table; F, F, F, F, heckles; G, G, back boards; I I, direction in which the holders swing; there were the same wheels, &c., at each end of the machine, and the holder table H reached from one to the other. The wheels C, C, with all attached to them, were made to rise and lower upon the heckles, and the back-boards G to rise when the heckle bench turned.

About the same time another patent was taken out for a machine, where the holders were suspended above one end of a travelling sheet of heckles. This machine also required hand labour to turn and transfer the stricks, though the tow was caused to fall clear from the heckles by mechanical means. The following sketch (*fig.* 586.) shows the principle upon which this machine works, and though never much employed at the time of its appearance, has subsequently served as a foundation for those that are now in the zenith of their prosperity.

A A (*fig.* 586.) sheet of heckles; B support for holders; C, C carrier pulleys for the sheet of heckles. *Fig.* 587., a larger view of the heckle bar G G, in order better to show the faller D D D in the staples or grooves E, E, and *fig.* 588. at the end of the heckle-bar G G; F, F, pins of the heckles, between the rows of which the faller D D D acts to push the tow off the pins. There is a clearing faller D to each heckle, which is kept to the bottom of the heckles at that part of their course where they are in contact with the flax, but at the turn F D fly beyond the points, as shown by the effect of the centrifugal force.

All these machines, possessing great similarity of features in regard to the personal





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attention required, never came into such general operation as to supersede entirely hand-dressing, either from their own defects or prejudices against their employment. About the year 1830, in consequence of the new mode of spinning, hereafter to be described, being carried on with considerable energy, it was found advantageous to cut the flax into 2, 3, or more lengths previously to heckling, which rendered it necessary to have machines peculiarly adapted for this new short description of material. This machine, known as the excentric or circular machine, deserves considerable attention for its own inherent merits, and the extensive utility it has proved to be of in suggesting the principal parts of those by which it has been supplanted. In its original form it was made of a breadth suitable for only one strick, and consisted of a cylinder 3 ft. diameter, upon the whole circumference of which at intervals of 3 or 4 inches were fixed the heckles. As each machine could only carry one description of heckle, it was necessary to employ a series of these machines, called a "class," when the flax required to be dressed over a succession of finer tools, each succeeding machine carrying a finer tool than its predecessor. The heckles were cleared of tow by coming in contact at one part of their revolution with a brush roller, which also revolved in contact with a cylinder covered with card clothing, the points of the pins being in such a direction as to clear the brush from tow, and allow itself to be in its turn cleared by the oscillations of a comb, whence by rollers the tow was brought into a sliver. In order to preserve the continuity of the supply of tow, and maintain the regularity of the sliver produced by it, the holders with the flax were presented to the heckle cylinder in a manner peculiar to this machine, and in endless succession by means of certain circular carriers placed at each end of the heckle cylinder, but excentric thereto, and at such a distance apart as each should bear one end of the holder as it extended across the cylinder parallel

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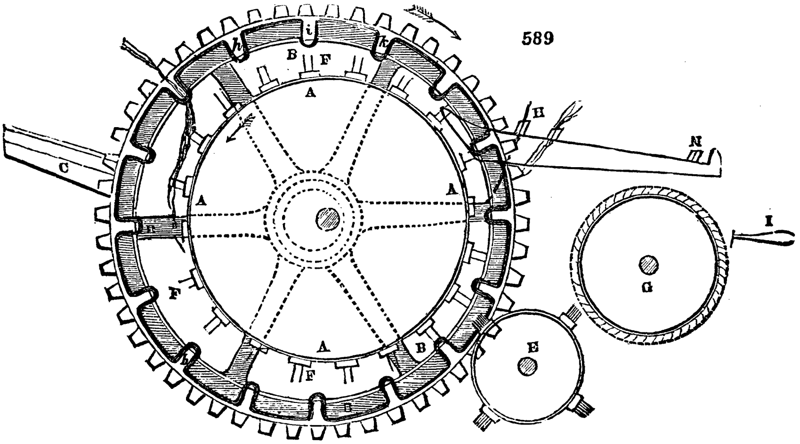

to its axle. Thus, the holders introduced at that part of the circumference of these carriers furthest from the heckles were carried forward, while the flax was in operation, till they were brought almost into contact with the points of the pins, when by the intervention of a slide they were withdrawn from the machine, but with one side only of the flax dressed, and that but on one tool; therefore, the holder required replacing in the same machine, in order that the second side of the strick should be dressed as was the first. The holders then required to be carried by hand to each succeeding machine of the class.

The preceding figure (589.) shows the leading features of these machines:

A A (*fig.* 589.) heckle cylinder; B B excentric wheel to carry holders in its recesses *h, h, h, h, h,*; C slide upon which the holders were laid so as to fall into the recesses *h, h* of wheel B; D slide for taking out holders; E brush cylinder with brushes; G cylinder covered with card clothing; H holder come out; I doffing comb. The space of the holder carrying wheel was filled with holders, and so maintained in endless succession, and thus each served in some measure to keep the end of its preceding one down into the heckles.

About 1833, a machine was patented consisting of two parallel cylinders, over which the flax was carried, revolving in its progress so as to present the alternate sides of the strick to the heckles, the progressively finer tools being ranged along these cylinders, so that having passed the length of one cylinder one end was completely finished. When the holder was taken out, "shifted," and replaced, it was carried back along the second cylinder, and thus returned to where it commenced, finished. This machine, however, never was carried further than the experimental one for the patent.

Another machine the same year made its appearance, and which for some time enjoyed much celebrity. It consisted of two parallel vertical sheets of heckles running together, and so geared that the heckles of one intersected the interstices of the other. The flax suspended in its holder from a species of trough passed between these two sheets, and was thus heckled simultaneously on each side in its course through the progressively finer heckles from one end of the machine to the other.

A, A (590.) heckle sheets; B B holder trough or slide; C, C, C, C, pulleys for carrying the heckle sheets; D, D brush rollers; E, E rollers covered with card clothing to clear the brushes; F, F doffer combs; G, G, G, G heckles; H holder; I, I brushes.

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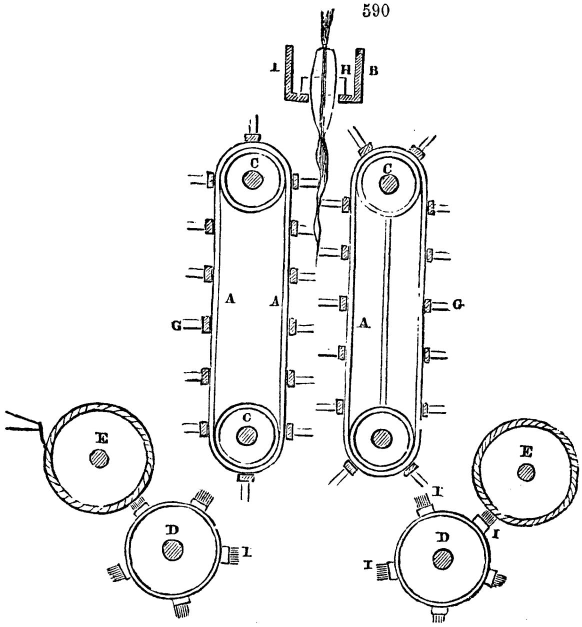

At about the same period a foreign machine was patented, known as Evans's machine, of which the following description will give a correct idea of its principle of action, and also of its holders, which are different from those already described.

There are two series of combs, see *fig.* 591., attached to two movable frames represented at *a* and *b*. Each frame is formed by vertical bars *a b*, with lateral branches or arms, which carry the heckle points. The branches or arms are parallel, and at equal distances apart, but fixed in such positions in each frame that they may occupy the intervening space when the frames are brought together as *fig.* 592. The frames are put in motion by means of revolving cranks to which they are attached as shown in *fig.* 592., and when the cranks turn upon their axes, the branches of one frame pass between those of the other without touching. This forms what may be called a set of combs; the points of the combs of one set being opposed to the points of the combs in the other set.

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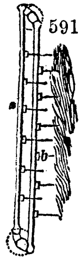

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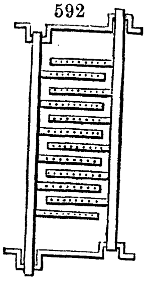

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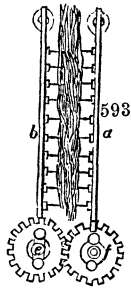

The way in which the series of combs that compose one set act upon the flax, is shown in the side view, *fig.* 591. When the cranks are nearly vertical, the points of both frames are away from the flax, but as the cranks move round in the direction of the arrows, the frames come into another position, and it is then that the points or heckles of one of the frames *a*, begin to penetrate the flax, and descending they comb or divide its fibres. The rotation of the cranks continuing, the two frames *a* and *b* come into the position shown at *fig.* 591., the points of the frame *a* withdrawing from the flax, and those of the frame *b* approaching and pushing the fibres off from the former, which are now combed by the descending stroke of the points.

It will hence be perceived that as the combs of the frame *a* and *b* respectively advance, they will push forward the whole of the strick of flax, and render it impossible for the fibres to be raised and entangled, as each frame in advancing clears the fibres from the points which preceded it.

A single set, however, of such combs or heckles acting only on one side of the flax would but imperfectly perform the operation of opening its fibres; it is therefore necessary, in order to accomplish the desired object in the most effectual way, that two such sets of combs or heckles should be brought to act on opposite sides of the strick of flax, suspended in the position shown in the figures. The cranks of the two opposite sets of comb-frames or heckles *a*, *b*, and *c*, *d*, are connected by a pair of toothed wheels *e*, *f*, as *fig.* 593., or by four toothed wheels, by which the heckles are actuated at once, the two sets moving in opposite directions, but with similar speeds, and the combing or heckling of the material will go on in the way shown in the figure last indicated. The tow being collected as drawn off the lower end of the sticks on to a slowly revolving cylinder or brush roller, whence it is doffed by a comb and delivery rollers.

The clamps or holders differ considerably from the clamps which are commonly used. I shall therefore particularly describe their construction, before showing them in operation. *Figs.* 594. and 595. are views of the clamp in two different positions; *a* and *b* are two boards united together by a hinge *c*, at top, which of course allows them to shut and open. The lower parts, forming the jaws of the clamps, are made with teeth or indentations, between which parts the ends of the flax or hemp are securely held when the clamps are brought together; *d d*, are two pieces projecting from the board *b*, at the end of each of which is an eye shown by dots, and at the back of the board *a*, (see *fig.* 594.) there is a double armed lever *e*, turning upon a fixed pin *f*, which lever carries two circular wedges *g g*. These wedges pass into the eyes of the pieces *d d*, when the clamps are closed, and hold them fast. There is a segment ratchet *h*, at the upper part of the board *a*, which turns upon a stud *i*, and is pressed downward by a spring *k*. This ratchet receives the end of the lever *e*, and consequently keeps the circular wedges firm in the eyes, which hold the clamps securely together, and prevent their opening by the shaking of the machine.

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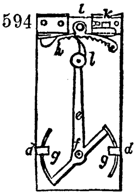

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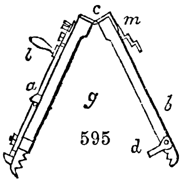

When it is required to open the clamps, the ratchet *h*, must be raised, and the lever *e* pushed aside by its handle *l*, which draws the circular wedge *f* from the eyes of the pieces *d d*, and the boards of the clamps immediately separate. For the convenience of suspending the holders in the machines, a piece of sheet iron *m* is bent at right angles, and fastened to the back of the board *b*, as seen in *fig.* 595., forming a groove by means of which the holders are enabled to slide into the machine and hang there.

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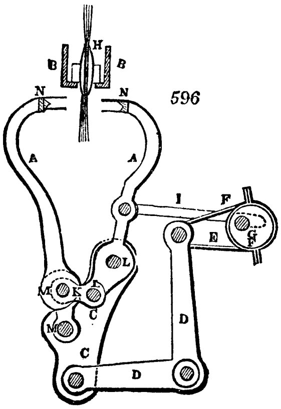
About the year 1840 an improvement took place in the excentric circular, by which one screw of the holder retained two stricks, and the machines made wide enough to take four stricks, and also a movement was made by which the holder was carried over two cylinders, so that each side of the strick was dressed before taking out. These improved machines had a very extensive sale, as wages and the necessity of attention were much reduced by them. Also the third machine, herein-before described, was revived, having a rising and falling motion for the holder support, and was known as the Belfast machine; and similar improvement was made in the double vertical sheet machine. But, as none of these sufficiently dressed the line for the finest yarns, a machine called the "crank machine" was invented for that purpose, but was in use for a very short time; its object was more to perfect the dressing after the excentric machine than to do the whole work itself. In this machine the flax was suspended, and then struck simultaneously on each side by heckles having an abrupt angular movement, first to strike into, and then draw down the line, in order to draw off the tow; the work was begun at the end and gradually advanced up to the holder.



A, A (*fig.* 596.) arms for carrying the heckles; B, B, trough or slide for holders; C C sliding piece to carry pivots or the carriers A, A, so as to rise and fall by the motion of the bell crank D; E connection of bell-crank D with excentric F, to give the downward stroke when the heckles are closed upon the flax by the action of the crank, G, connected by arm I with the carrier A; H holder; K connecting rod for the carriers A, A; L and M pivots for the respective carriers A, A; N, N the heckles.

This machine, capable of doing the work but very slowly, and with great expense of heckles, was attempted to be improved upon by another made of two parallel cylinders constructed of a series of bars running at equal speeds in contrary directions. Upon these bars were fixed the heckles, which were kept in a horizontal position during their entire revolution, by a crank at the end of each bar, guided in a circular path excentric to that of the bars themselves. The flax suspended passed with a rising and falling motion from one end of the machine to the other, each succeeding heckle being finer than its preceding.

A A (*fig.* 597.) circular discs keyed to the shafts B, B; C, C circular discs running upon the excentric bosses D, D; E, E heckle bars; F slide for holders; G holder.

The discs A, A are alike at each end of the machine, and have suitable bearings to

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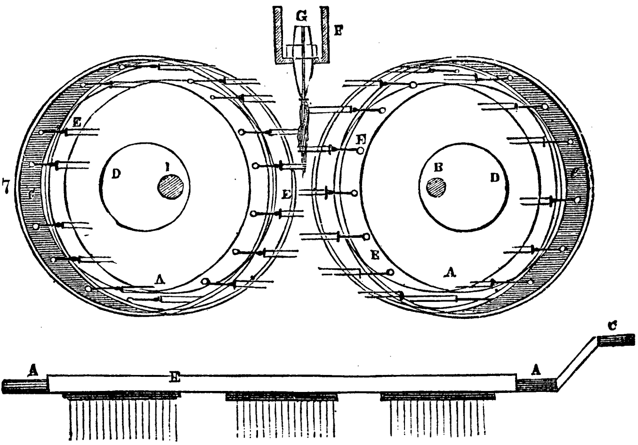

carry the heckle shafts E by their round necks A, A. The discs C, C have similar and equal number of bearings to carry the cranked ends of the heckle bars C, and are carried round by them from the movement communicated to A A. By this arrangement the pins of the heckle are always in the position shown, and penetrate the flax at right angles to its length.

As all the preceding machines have now passed into oblivion, it may be as well to trace the reasons. The fault of the first was the great attention it required to turn the stricks and to carry them by hand from tool to tool; the want of the rising and falling motion caused the heckles to strike at once into the middle of the flax, thereby reducing the yield of line, and rendering the tow knotty and torn. Though some of these defects were remedied in the second, there still remained the transferring of the flax the taking out of the tow, to be performed by the attendant, and the motion of the line through air was objectionable. In the third another step was gained, that of taking out the tow; but, for the want of the rising and falling, the work was too abruptly torn into. The fourth was suitable but for short flax; it was very expensive on account of the liability of the holders falling upon the heckles, and the turning and transferring the flax by hand, even when afterwards these expenses were slightly reduced by the improvement above alluded to. The fifth, never coming out of the workshop, was perhaps found deficient for want of the rising and falling, which, though partially obviated by the cylinder end being conical, might, even by this mode of palliation, lead to further difficulties of a practical nature, aud by the turning movement being continued, a further inconvenience would no doubt have been found in the edges of the stricks being as long exposed to the heckles as the sides. The sixth, for a long time popular, was found, by heckling both sides at the same time, to tear away the flax, and from the impossibility of getting the pins to work near up to the holder, a long shift was required,—another reason by which the yield was reduced. Seventh; Evans' machine, though only put up for experiment in this country, has been more extensively tried abroad; but it made tow so knotty for want of a clear stroke through, that it was immediately, and is now perhaps entirely, abandoned everywhere. Eighth; the crank machine was very troublesome and expensive, and could hardly ever be said to have got beyond its experimental state. It is now altogether laid aside. Ninth; the double cylinder machine answers well for very short line, but, for much the same reason as the above, makes but indifferent tow, and its use is now nearly discontinued.

Besides the above there have been several others patented; some have never been wholly constructed, and others never been used: neither appear to have suggested any principles or modes of action capable of being modified into a useful or practical state.

We now come to explain those heckling machines by which the flax-spinning trade is at present actually carried on, in which it will be seen that the best parts of all the preceding are combined, so as to form machines of the utmost efficiency, and capable of working with a closer approximation to the utmost degree of economy.

The first in order is the transverse sheet machine. This machine is on the same principle as the third, above described, having a horizontal sheet to each heckle, but each running in an opposite direction, and a rising and falling trough, along which the holders are impelled from one end of the machine to the other. It is so arranged, that when one side of the strick is heckled the slide or trough rises, and the holder being

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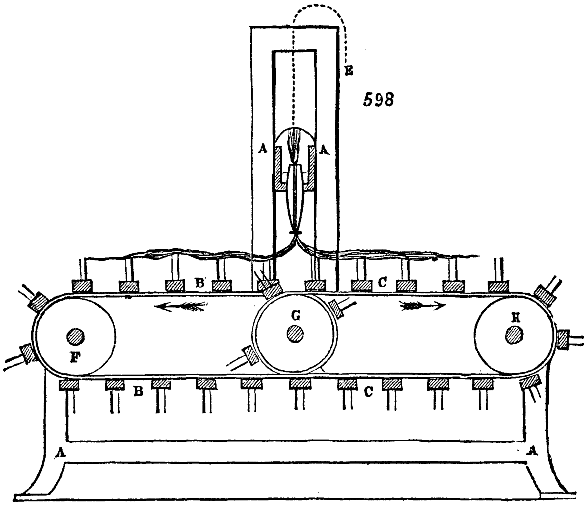

suddenly pushed forward, the flax thereto attached comes in contact with the next sheet running in a reverse direction, and has thereby its other side dressed. This is repeated over as many tools as may be desired, generally three, but sometimes four. For the better elucidation refer to *fig.* 598., section of machine.

A A (*fig.* 598.) frame; B B heckle bearing sheet running in the direction of the arrow, C C another heckle sheet running in the opposite direction; D holder, and its rising and falling support in the form of a trough, along which it slides from one end of the machine to the other; E chain to which is attached the balance weight of slides, &c.; F, G, H the carriers of the sheets, of which F and H are keyed to their respective shafts, as it is by them the sheets B, B and C, C are driven, and drive their carriers G loose upon the shaft.

It is somewhat objectionable in the above machine, that the holder slide has to rise to a great height, so as to take the ends completely off the tool, otherwise the strick is liable to be crossed by one side being for the moment pulled in one direction, and the other in a contrary; and also that the tow and waste might be apt to collect in the spaces where the sheets cross each other, and thus occasion derangement.

The following, known as Baxter's self-acting cylinder and sheet machines (these appellations being given accordingly as cylinders or endless sheets were employed to carry the heckles), of which the distinctive feature is turning the holders, avoids this inconvenience.

The holders from which the flax is suspended are supported above the centre of the cylinder (when a cylinder is employed), or of the rotatory carrier of the endless sheet, when that method of applying the heckles is adopted; but instead of their supporting slide or trough being in one continuous piece, it is divided, according as the machine is intended for 3 or 4 gradations of tools, into 6 or 8 divisions, each equal to the length of the holder. Of these half the number always remain in a direction parallel to the axis of the cylinder, while the others, placed between or alternately with them, are connected together by gearing, so as to turn simultaneously in a horizontal direction, and the whole are combined to approach and recede to and from the heckles together by a falling and rising motion. The brushes, card-clothed cylinder, and comb, when employed, are similarly combined for clearing and delivering the tow as those already described for the same purpose in the excentric circular machine; but in general for the sheet machines a simple faller is found sufficient. Thus, the flax introduced into the first division when the slide is at the top of its course, is dressed during its descent, and "dwell" upon the first half length of the first tool; on being risen it is pushed forward by mechanism into the next division of the slide, which then by turning half round, or end for end, presents the second side of the strick to the second half of the same tool, upon which it thus becomes dressed, as was the first: on again rising, the flax is pushed into the third division of the slide, which presents the side of the strick that was second on the first tool to be first exposed to the action of the second, and thus, at each rise, is the flax advanced towards the finer tools, turning at each alternate advance, till the required number of tools is passed over. This is the construction generally employed, but it is sometimes necessary that each holder turns in its place, thus heckling each side of the strick on the same identical heckle; thus the flax is more worked, for it is exposed to 6 or 8 gradations of tools, instead of 3 or 4 by the other method, but a machine upon the former will do nearly double the weight of flax than upon the latter mode of working. Though the progress but of one holder has here been traced, it must be understood that there are necessarily 6 or 8 in simultaneous operation, according to the description of machine; for the propelling motion being at one end requires the full complement of holders to push one another forward. This machine and the last perform pretty nearly the same quantity of work, which, with 6 or 7 boys, amounts to about 1 cwt. per hour, and are applicable for long flax, and for cut as far as 60 or 70 leas; the latter is sometimes used with 4 gradations of tools as far as 100 leas. The construction of these machines, whether cylinder or sheet, is so similar, that the same letters and figures refer to the same parts of each. *Figs.* 599. and 600. front and profile views of cylinder machine, and *Figs.* 601. and 602. front and profile of sheet machine.

A A general framing; B driving pulley on the shaft of brush roller; C C main cylinder; D D brush roller; E E card-covered roller; F, F rails constituting part of the falling and rising head, and to which are fixed the movable parts for turning the holder; G G the first part of the slides along which the holders pass; H, H the alternate turning parts; I, I the holders, those No. 1. are with the side as put in, and those No. 2. are when turned; K, K, K supports from the rail F to fixed parts of slides G; L the supports with pivots for the turning parts of the slide H H; to these pivots are fixed respectively the wheels *m, o, q;* the intermediate wheels *n, p* being loose upon their axis, serve to connect the motion of the series; R lever and lock to retain the wheels fixed during the fall and rise; S support for the lever R; T support for the pendulous lever U, which by the pusher V drives the holders forward when introduced into the slide; W slide inclined to conduct the holders on a table; X X doffing comb shaft; Y connector between the rails F and balance weight lever Z; *a a* excentric to give the up and down motion to moving head *b* friction bowl; *c* balance weight: this arrangement of connector, lever weight and excentrics are the same at each end of the machine, as the shaft *d*, upon which the excentries are fixed, extends the whole length of the machine; *e*, *f*, *g* train of wheels and pinions to reduce the speed of cylinder shaft *c* to the excentric shaft *d*; *h*, *i* wheel and pinions to drive the excentric by which the doffing comb is moved by the connecting rod *l*, *m*, *n*, *o*, *p*, *q* trains of wheels from driving pulley B to cylinder C and card roller E; the propulsion of the holders is caused by the radial movement of the lever *z*

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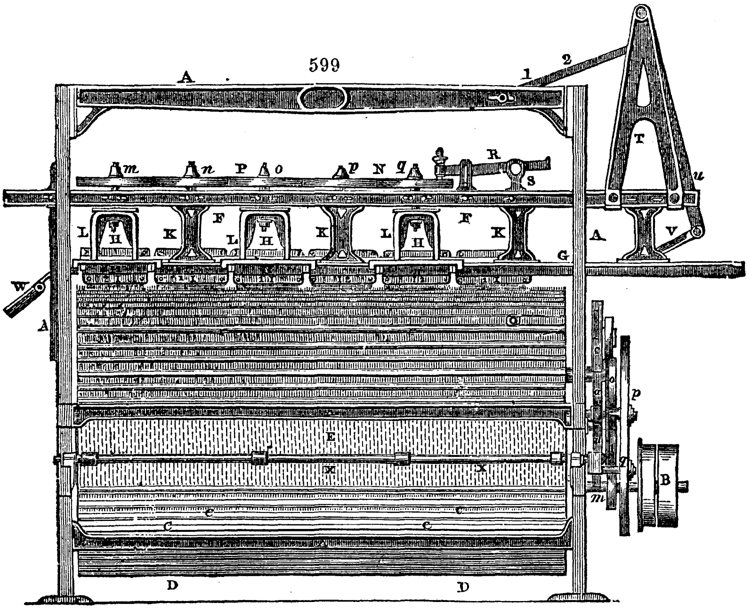

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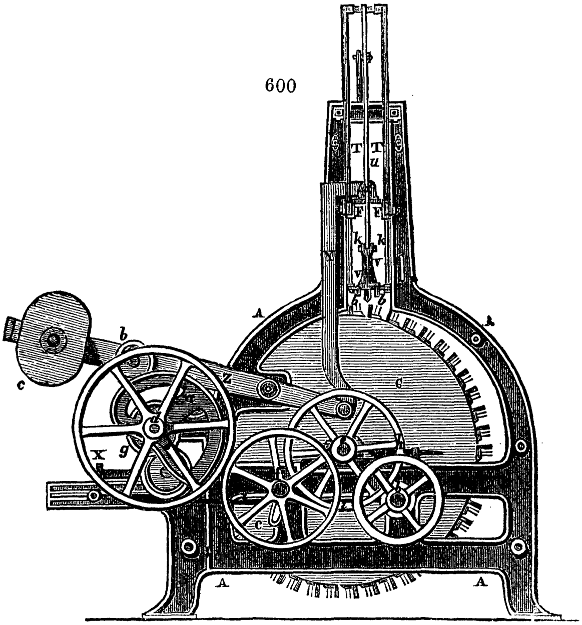
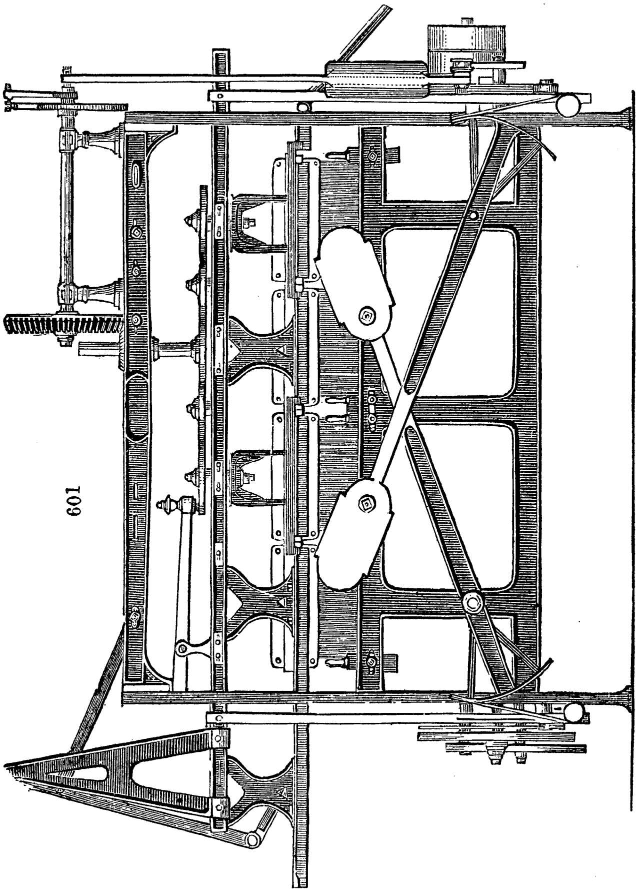


caused by the rise and fall of the head. The following figures show the form of the "sheet" machines, but which do not, from their similarity of principle and construction to the foregoing, require a detailed description; as the only differences are



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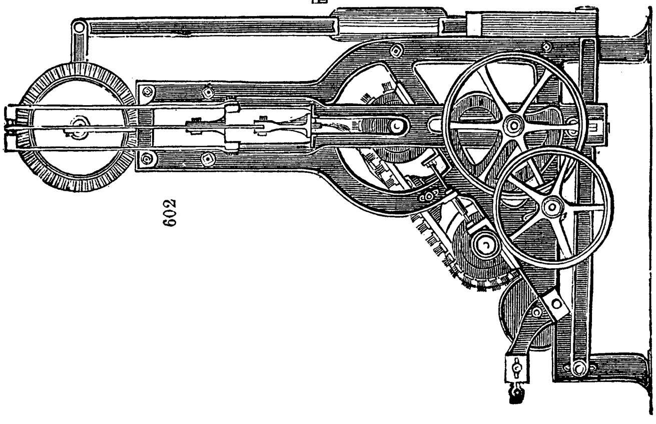

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that a sheet is used to carry the heckles instead of a cylinder, and doffer bars fo knocking out the tow instead of the more complicated arrangement of brush, comb, &c.

Those machines that are now employed for finest work are called *Marsden's intersecting machine*, and *combined intersecting*.

The *intersecting machine* is so called from the peculiarity of its construction, being somewhat similar in principle to that already described, of two cylinders of heckles carried on cranked bars, but instead of their being so closely placed together, there are but six, eight, or more bars bearing the heckles, forming as it were a sort of a skeleton cylinder, of which there are two, parallel to each other in each machine: the flax passes along the machine between these two cylinders, and is struck by their heckles alternately, and in successive order on its opposite side. *Marsden's combined intersecting machine* has in addition to these cylinders a pair of sheets of heckles, by which the first tool work is performed previously to the flax arriving at the intersecting cylinders, and the flax is rather more severely heckled. In both of these machines the holder slide is provided with a rising and falling motion, as being absolutely necessary for the production of good work: these machines penetrate the flax better than the cylinder, as from its position between the heckles, the flax is rigorously exposed to their effect, but the tow thereby produced is rather more lumpy and uneven, and is, therefore, considered inferior to that from the cylinder machines, see *figs.* 603. 604. 605. of combined intersecting machine.

Fig. 603. end view; *fig.* 604. side view; *fig.* 605. sheets; *fig.* 606. holder; A A A framing; B B holder trough or slide; C jointed rod, having a horizontal motion to push forward the holders by the clicks *a*, *a*, which catch the holders in one direction only; D pendulous

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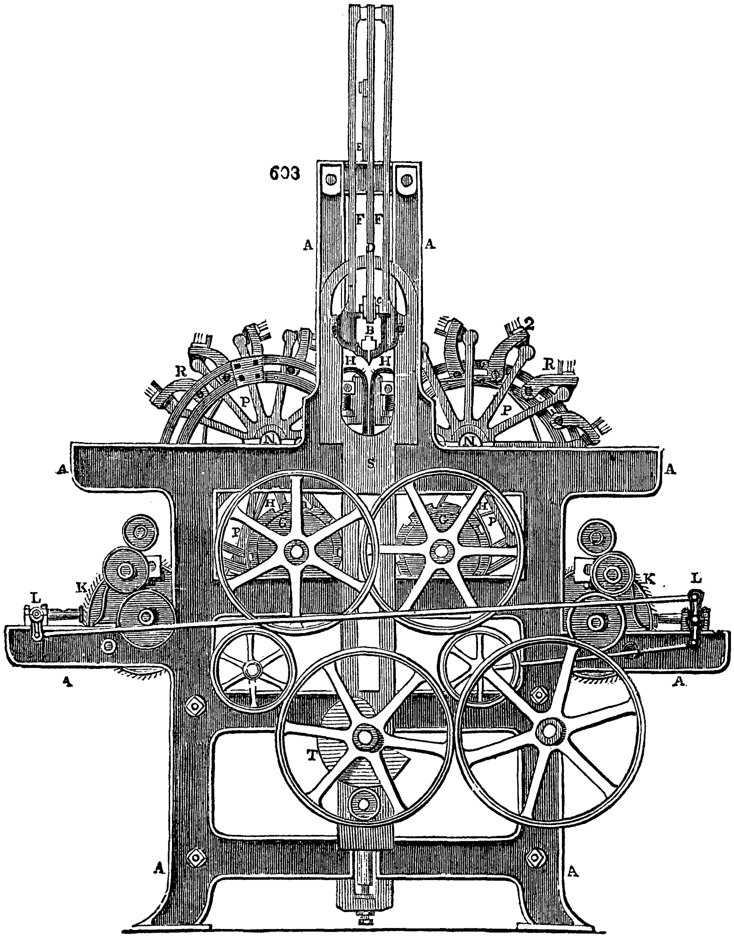

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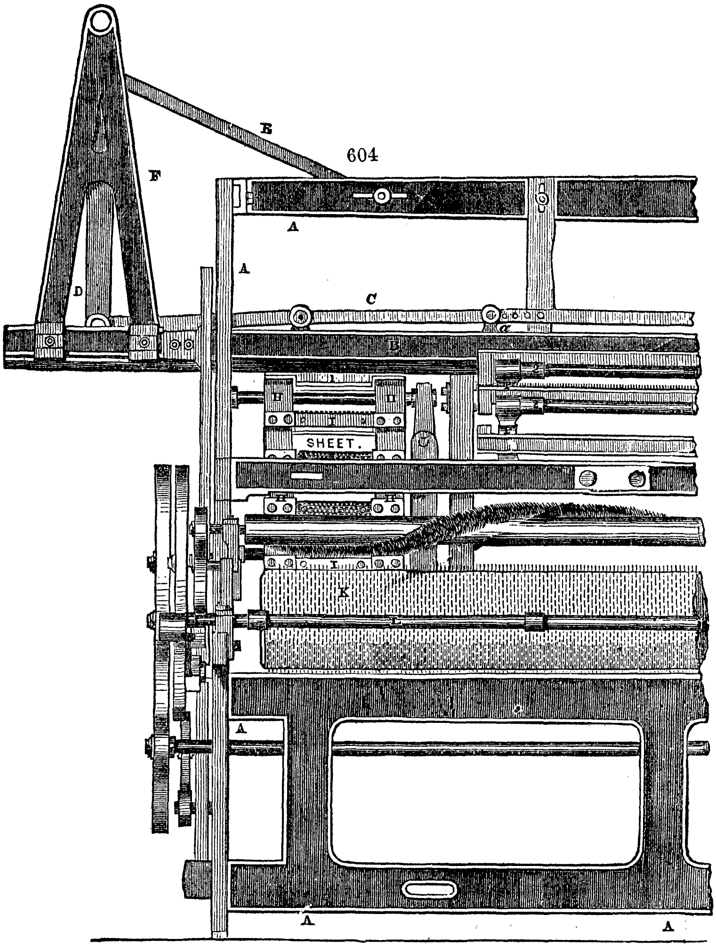
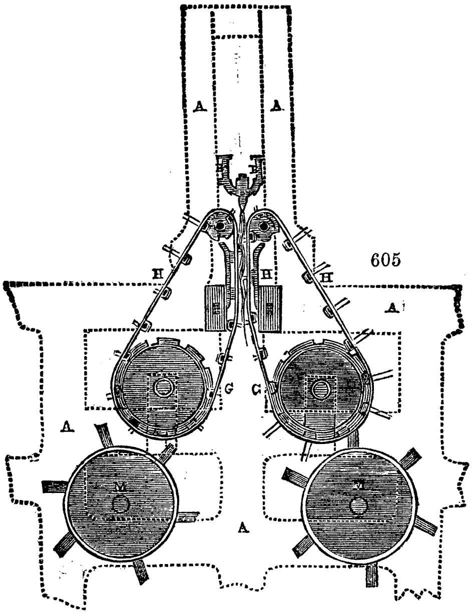


ever receiving a reciprocity motion from the radial arm E, at the rising and falling of the sliding head; F support for the pendulous lever D; G, G carriers of the heckle bearing sheets, H, H; I, I heckles fixed to the sheets or straps H; K K card-clothed cylinder for receiving the tow from the brush cylinder; L doffing comb; M brush cylinder; N N, *o o* slide shafts, upon which are keyed the carrier arms P, P of the intersecting heckle bars Q, Q: R, R crank arms fixed to the heckle bars, and guided by their extremities in the slides *o*, *o*, by which the peculiar position of the heckles is maintained; S, connector between sliding head and lifter excentric, or cam; T, U the friction bowl for pulling downwards the slide head, to which a tendency is given to rise by balance weights, not necessary to be shown; V wheel commanding excentric to give the oscillations to the doffing combs.

In all heckling machines, whether those of sheets or cylinders running in opposite directions, and not therefore requiring the turning motion for the holder, or those with the turning motion, and having therefore but one sheet or cylinder; or again those called the intersecting and combined intersecting, the hand labour required, and the number of holders or work turned out in a given time, are nearly the same for similar degrees of dressing, and all these machines are provided with change pinions, to increase or diminish the quantity of heckling in any required degree.

The hand labour consists, first, of dividing the flax into stricks, for long flax, of 4 or 5 ozs. each, and for cut, 1½ to 2 ozs. Then screwing these into the holders, and when one end is worked, taking out the holders, performing the "shift," and replacing them,



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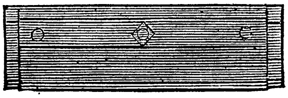

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by which it is evident that the manual work is reduced to nearly the lowest possible point; for the taking out the holder and performing the shift are the only operations that can by possibility be done mechanically; and it is desirable that this should be so effected, not only with a view of saving the expense in wages, but to avoid the waste and entanglement, and consequent reduction of yield, to which by handling the flax is exposed, and at the same time reduce to the utmost degree all need for reliance upon the care and attention of the workers employed. A holder with this intention was patented about three years since, which, from its novelty of construction, deserves a record, for though not yet in active operation, it only requires time to remove the groundless prejudices opposed alike to this as to all other innovations.

Previously, however, to entering upon a description of this holder, it will be necessary, in order to make our account of heckling machines now actually in use complete, to describe one much used in France, and patented for that country, January, 1846. It is there known as the *peigneuse mecanique system Busk*, from the name of its inventor, an English machinist (whose transferring excentric and double cylinder machines have already been described).

Flax heckle, called *Peigneuse Mécanique, on the system of Busk*, as described in a French *publication industriel.*—It has been found in practice that to obtain the best results, it is absolutely necessary to attack the flax by the end of the strick, and to continue it slowly and gradually till the points of the heckle act on the middle; then to obtain the greatest product in long line and the best quality of tow, it is necessary to heckle it alternately on each side of the strick, continuing thus on the first, second, third and fourth heckle, &c.

The machine which we offer to the public as the invention of Mr. Busk, the author of many ameliorations in flax-spinning machines, unites in itself all the different points of perfection indicated, without any of the inconveniences of the rival systems. The force requisite to drive it is hardly one-half of a horse-power; is capable of heckling on any number of heckles, and without increase of hand-work, about 500 kilogrammes ($\frac{1}{2}$ ton) daily, more or less, according to the nature of the flax. It is applied with equal advantage to the long or the cut line. It may be conducted or managed by

4 or 5 children merely, employed to screw and unscrew the clamps (presses), an easy operation.

Description of the machine. — *Fig.* 607. longitudinal elevation of the mechanical heckle.

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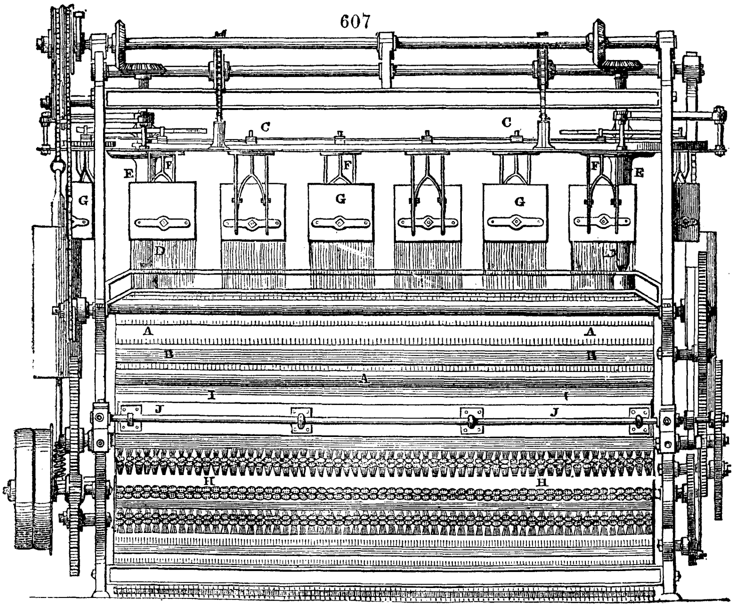
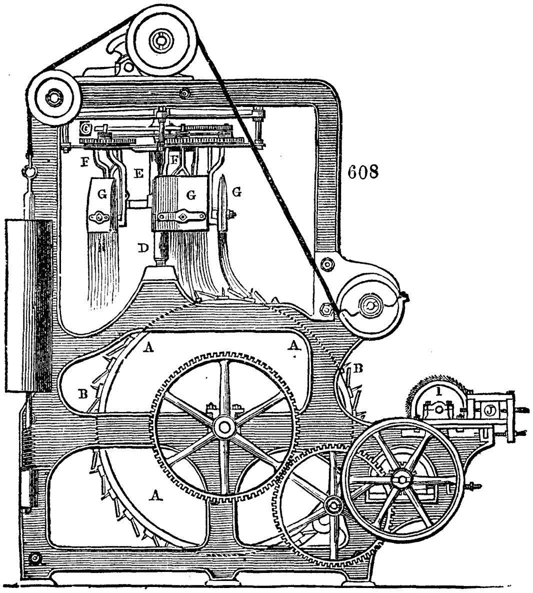


Fig. 608. Elevation of one of the sides, or as seen from the end.



A. Large cylinder, in whose circumference the heckle teeth are fixed. The distance between the points varies according to the perfection which is desired in the heckling, and the quality of the flax. The length of the cylinder (2 metres 40 cents) admits of multiplying the heckle points, and varying their distances.

B. Small plates (*planchettes*) fixed between the heckles, to determine the depth to which the points shall act in heckling. These plates are moveable, so as to be arranged at pleasure.

C. Carriage bearing the pincers in which the stricks are fixed. D. Upright arbours on which the carriage rises and falls by means of the sockets E, fixed to the carriage, to guide its ascent and descent, effected by aid of an excentric placed on the side of the machine. This carriage is balanced by counter weights. One of its sides is furnished throughout all its length with a cast-iron rack, in which all the pincer bearers (which are toothed on their upper part) work.

F. The pincer carriers, whose upper part is a toothed wheel, and whose lower part terminates in hooks (*crochets*) that receive the pincers in wood. Rigid bars connect the pincers in the upper part; so that they all work at the same time.

G. Wooden pincers clasping the stricks of flax by means of a screw.

H. Cylinder with brushes for removing the tow, which had been retained by the heckle points, and carrying them to the cylinder I, furnished with cards.

J. Heckle which deposits its tow into a box placed to receive it. All the pincers G being furnished with flax are fixed in the hooks of the pincer bearers. On setting the machine in motion, the carriage G, commanded by an excentric intended to give it a progressive velocity, calculated proportionally to the thickness of the strick, descends and puts the flax in contact with the heckle teeth fixed round the large cylinder A, actuated by a continuous movement. When this operation is terminated, all the stricks of flax submitted to the action of the cylinder having been heckled on one side, the excentric, which had caused the carriage to descend, makes it mount again; at which moment the other excentric acts destined to communicate to all the pincers the horizontal motion; and, as the pincer bearers are in toothed geer with the carriage, the consequence is that in advancing the pincer bearers pivot on themselves, so that the carriage descending anew, presents to the action of the heckle points the other face of the flax.

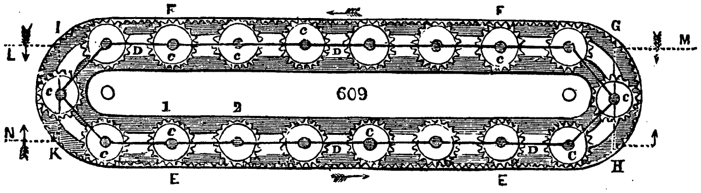
This action in being thus repeated even to the extremity of the carriage, works on the flax by heckle teeth closer and closer together. When they have arrived at this point, the pincer carriers continue to advance, passing by the back of the machine: but this side of the carriage having no rackwork, the pincer bearers do not pivot (turn round) and proceed without changing position, at which point the heckled flax is replaced by the unheckled.

The tow is disengaged by the brush-cylinder, and transmitted to the cylinder mounted with cards: a heckle then detaches it and drops it into a box.

Such was the state of heckling machines when the holder above alluded to was first contrived with a view of being applied to this machine, for which it is peculiarly adapted.

All the holders that have hitherto been used are similar to those described at the beginning of the article, consisting of two clamps of wood or iron pressed together by screws, except in Evans's machine, where an inclined plane was used for that purpose. But the holders now referred to are on an entirely different principle; the holding pressure being produced by the effect of leverage of the clamps or jaws themselves, which are for this reason, and also for better supporting the end of flax out of operation, made from 7 to 9 inches broad; and while one of their edges are hooked or fastened together by a pair of double-acting hinges, similar to those used at the bottom of turnpike-gates, the others are held together by a clasp, and thus the flax is very firmly grasped or held by the pressure at the joint or hinge, and the end of the flax not exposed to the heckle is held vertical and straight by the breadth of the clamps. These holders do not slide of themselves along a trough, as do the other description, but there are "carriers" for them attached to the sliding and turning apparatus, by which they are carried forward and turned as desired. These carriers are so constructed as to retain the holder by one of its clamps or jaws always vertical, but leaves the other free to fold from one side to the other; when this folding takes place, which is during the dwell of the other holders upon the heckles, that end of the flax which was contained between the clamp becomes liberated, and the previously pendant one is lapped up and enclosed between them, when the rise of the head taking place, the catch replaces itself, and the holder is carried forward to return along the second cylinder of the machine, and ultimately arrives at the place where it was first put in with the line completely dressed. As all these movements are performed automatically by the machine itself, the whole of the wages necessary, when the other holders are used, for taking out, and screwing & unscrewing ing, and replacing them, amounting to nearly half of the whole expense, is saved, besides much indirect trouble and confusion.

A 1, A 2, jaws of the holder; B B carriage or frame for supporting the holder; C C, a toothed wheel, having a groove on one side to allow it to be carried by the rails of th moving head of the machine, of which *fig.* 609, is a plan or bird's-eye view; D, D, links or bars connecting the series of wheels C, C. These wheels are of such a diameter, that



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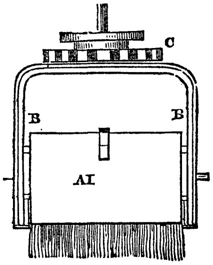

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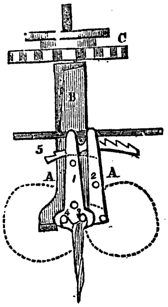
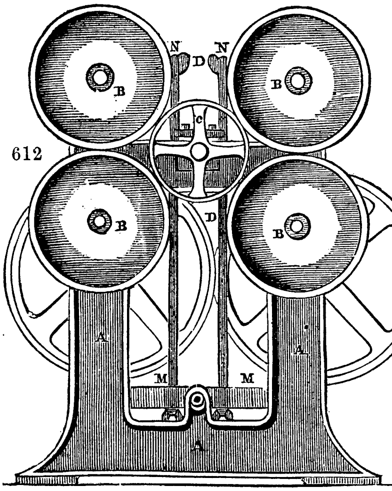


when propelled from 1 to 2, they will at the same time make one exact half revolution; and thus the holder attached to each presents its opposite side to the heckles at each advance similar to other machines. To cause this half revolution, the teeth of the wheels C, C engage those of the racks E, E and F, F; but the slides are so made as to maintain the wheels in one position from E to F at one end of the machine, and from F to E at the other; G H the position and place where the holder stands to be shifted; and I K when first put in or to be taken out of the machine; L M, axis of heckle cylinder to dress the flax after "shifting;" therefore its coarser tools are at end M; N O axis of cylinder for dressing the root ends; therefore, its coarser tools are at end N. The arrows show the direction of movement of all these parts. The mode of action of the holder is as follows. The jaw A 2 is first laid upon a table, and the flax placed upon it, when the jaw A 1 is caused to engage the pin 3, which are similar at each end of the holder, when it is folded down upon A 2, and the catch fixed to 2 engages the rack fixed to A 2 at 5, and the whole is firmly combined together and placed into the carrier, and maintained by the pins projecting for the purpose from A 1 entering into vertical grooves in the carrier, when, having passed over the heckles on cylinder N O, it ultimately arrives at G H, when, during the descent of the sliding head, the lever attached to the catch 5 strikes against a fixed point, and is thereby lifted out of the rack, thus leaving at liberty the jaw A 2 to turn. This is effected by a projecting pin 2, being actuated by a crank having a suitable intermitting motion, which carries it in the direction of the dotted line, while the hinge pins quit recess 3, and the other enters the recess 4, and the rack engages the catch opposite to the one it has quitted; and thus the shift is completed with a length equal to the thickness of the holder at 3, 4.

The cutting of flax, which is done in order the better to select and separate its various qualities, is an operation of some delicacy, and requires a peculiar machine for the purpose, which, though not complicated, requires great nicety in its making and arrangement; for the flax must not be cut too abruptly, but be gradually reduced to a taper and somewhat natural end. The cutting should be done before the flax is heckled. The machine for the purpose consists of a species of circular saw about 20 in. diameter; but, instead of a single blade, is constructed of 3 or 4 plates of steel, each about $\frac{1}{4}$ in. thick, and having angular projections from their circumference. This revolves at a considerable velocity, while the flax firmly grasped in each hand by its ends, is still further held and slowly carried against the saw by two pair of grooved pulleys pressed together by a considerable weight. It is thus partly sawn and partly broken through. Flax may be cut into 2, 3, and sometimes 4 divisions: and sometimes the dead harsh fibres that are frequently found at each of its ends only are cut off and used as tow; but more generally the different portions are heckled and used for the purposes they are sorted for.

Description of flax cutting machine. (*figs.* 612, 613.) A A, framing; B, the grooved pulleys for holding and carrying the flax; C C, the driving pulley; D, saw or cutter;

612



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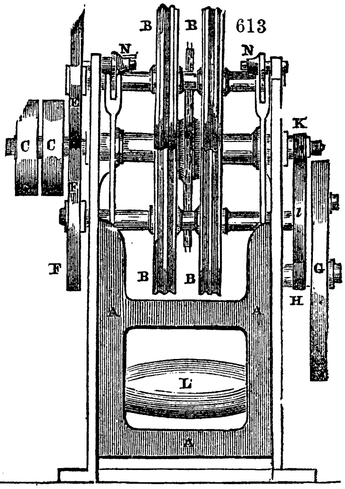

E, F, wheels for geering together the pair of holding pulleys; G, H, I, K, pinions and wheels for producing the proper relative speeds between the cutter and pulleys; L, weight, which by levers M and N, causes the pressure of the holding pulleys.

4th. *Preparing.*—By this term is understood those preliminary operations through which both line and tow must pass after the heckling and before the spinning process.

The mechanism and modes of proceeding for this purpose, which consist of repeated drawings, are similar for "long" line or "cut;" though the dimensions and fineness of the machinery must be made suitable for their various lengths and qualities. But in the preparation of tow a peculiar additional operation is demanded, as a consequence of the different state of the fibres of which the material is composed; this operation, termed "carding," has for object to bring the highly irregular and entangled mass into a somewhat more homogeneous and uniform state, previously to its being afterwards drawn and equalised in a manner similar to line.

In the preparation of line the first operation is called "spreading," and the machine employed a "spreader," or first drawing: those subsequently are the second and third "drawings" (sometimes a fourth is used), and lastly the "roving." It is upon the spreader that the separate stricks of line are first combined and drawn into long uniform bands or ribbons, called "slivers," of determinate lengths. This is effected by subdividing the stricks into two or three portions, and then placing them consecutively slightly elongated; and overlaying each other about ¾ths of their length upon and in the direction of an endless creeping sheet or apron. The machines are generally made with two of these creeping sheets or aprons, and upon each sheet are thus laid two distinct lines of stricks; each of which forms a thick uniform body of line, capable of being maintained to an indefinite length. These endless creeping sheets supply continuously another part of the machine, where the body of "line" is drawn out to between 20 and 60 times its original length, according to whether it is composed of cut or long flax. This part of the machine comprises a pair of holding or back rollers; an endless succession of bars called fallers, bearing combs of closely ranged steel pins, through which the slivers are drawn; a pair of drawing rollers; an arrangement of diagonal or doubling bars; and a pair of delivering rollers; is generally termed the "gill frame," or "gill head," probably from the French word "aiguilles" (needles), as descriptive of the combs, and to distinguish this machine from those formerly used for the same purpose, which simply consisted of a series of rollers under and over which the line was passed.

The following figures 614, 615, show the outline of the present most approved gill spreader or first drawing.

A A, general frame of the machine; B, driving pulleys; C, auxiliary frame for endless sheets; D, D, D, D, rollers for carrying the endless sheets or aprons; E, E, conductors to guide and slightly condense the four bodies or slivers of line; F, can for receiving the sliver; G, lever for weight on front or drawing roller; H, lever for weight on back roller; K, delivering roller shaft, spring and bell, which, by the intervention of geering between it and the front roller, is caused to ring when any desired length of sliver is delivered.

a a, the iron drawing roller or boss; *b b b*, the woollen or pressing roller, by the pressure of which upon *a a* the sliver is held during the greater velocity of these rollers over that of *c*; the holding or back rollers elongate in exact proportion of its augmentation; the holding roller *c* is in like manner pressed against another in order to assist the "gills" in retaining the fibres; *k, k,* hooked rods to connect the weighted lever *h* with the holding roller *c,* and by the pressure thus caused insure its effect; *dd,* the sheet or surface of "gills" composed of separate bars, as seen at *fig.* 614*, 615.*; *e,* rubber or cleaner of pressing roller *b*; *f, f,* conductors to contract laterally the sliver at the moment of drawing; *g,* plate of metal having diagonal openings at an angle of 45° (this plate is sometimes called the "doubling bars," having been first made of separate bars) to the original course of the sliver, in order to enable it to be turned in a rectangular direction and guided to the delivering rollers *h,h*; this direction of the sliver is more distinctly seen at *fig.* 617.; *i,* hanger or connector of pressing roller *b* to its weight lever *c*; *l, l,* the screws or worm shaft for carrying the gill bar *dd*; *mm,* the shaft with bevel wheels by which the screws

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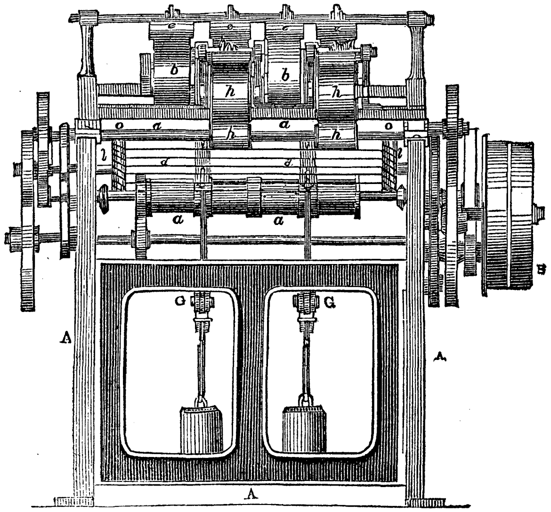

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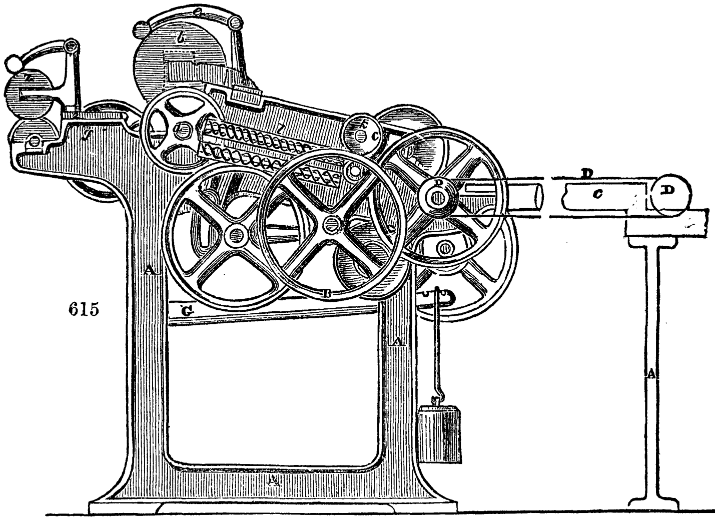
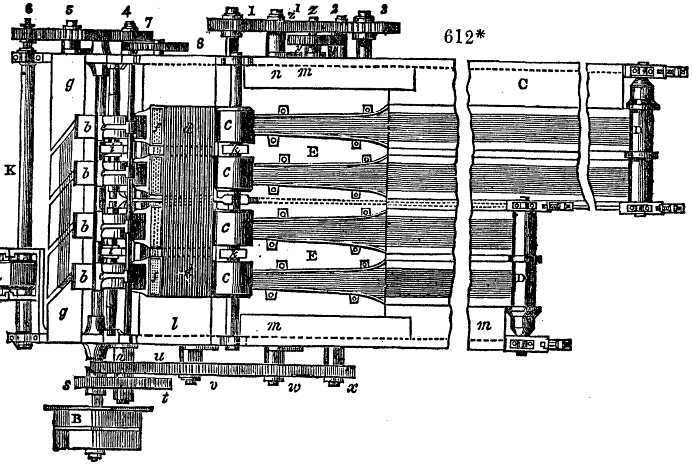


at opposite sides of the frame are caused to move simultaneously; *n,n,* pinions for connecting the upper and lower spirals of each pair; *oo,* the cams or excentrics for lowering and raising the gill bars; *pp,* weighted guide lever or bell cranks for guiding the faller

612*



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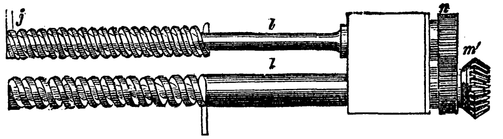

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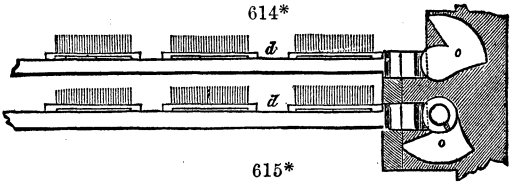

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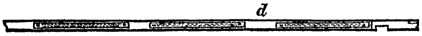

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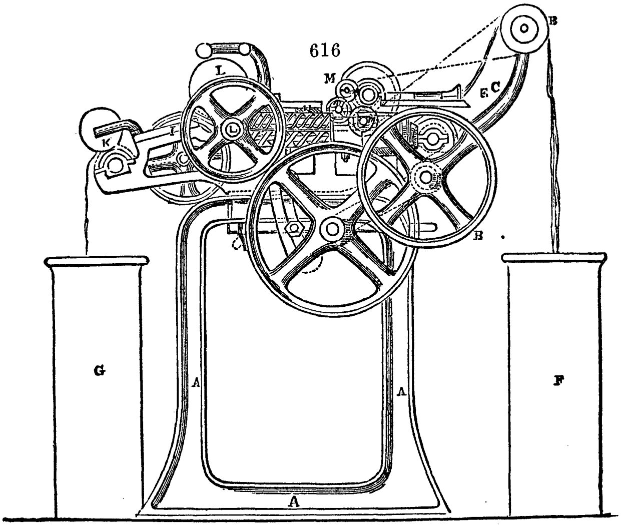
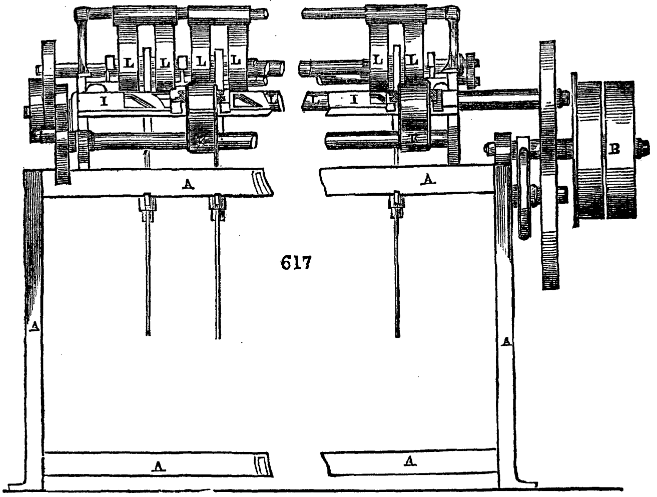


in its descent, and moderating the shock caused by its weight when coming in contact with the lower slide or support; *q* and *r*, worm and wheel for bell motion; *s*, *t*, *u*, *v*, *w*, *x*, line of wheels from pulley to front roller and from front roller to back; 1, 2, 3, line of geering from back roller to sheet; 4, 5, 6, 7, line of geering from roller to delivering roller; 8, front roller to brush; *y y*, from back shaft to back roller.

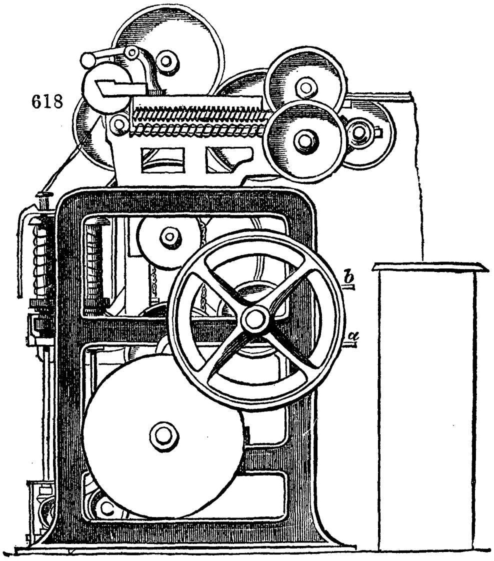
The machines for the second, third, and fourth drawings, though in principle essentially the same, yet differ in some of their minor details from the foregoing, as they do not require the feeding sheet to supply them, the "sliver," from the spreader having sufficient coherence as to allow itself to be drawn from the cans direct by the back rollers of these machines—neither is a bell motion requisite to determine the length of slivers produced by them. The subjoined sketches show the general parts requisite (*figs*. 616, 617.)


617

A A (*fig*. 616. 617.), framing; B, driving pulley; C, support of sliver carrier; D, roller for carrying sliver; E, conductors; F, can containing the slivers from the first drawing; G, receiving can; H H, the heckle carrying spirals; I, the diagonal or doubling bars; K, delivering rollers; L, the drawing rollers; *m*, *m*, *m*, the retaining rollers.

The roving frame is the same in regard to the arrangement of its back and front

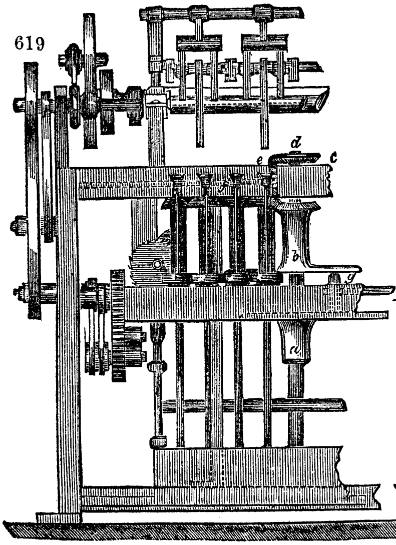
618



rollers and gills, as the drawing frames; and as the position and manner of regulating the spoles are generally the same as adopted for cotton, the description of these parts therefore does not require to be repeated; but an improvement patented a few years since by Mr. P. Fairbairn, of Leeds, of that part of these frames which relates to regulating the taking up movement of the bobbin merits particular attention, as by it the inconveniences of the older method of a weighted belt and cone, and those of the more recent disc frames, are entirely overcome. The principle of this improvement consists of driving a pulley by pressure between two discs running at equal speeds in opposite directions, as seen at *figs.* 618, 619, 620.

Figs. 618, 619. To obtain the variable speed, instead of using a cone and belt as in some frames, or the pulley and single disc as in others, *a b*, the horizontal driving discs, the lower one *a* is keyed to the shaft *d*, while the upper *b* is free to turn upon it; *i*, bevel wheel fitted to or forming one piece with the upper disc *b*; *c* bevel wheel keyed to shaft *d*; *e* intermediate bevel wheel geering in the bevel wheels *c* and *i*, so as to turn them in opposite directions, and consequently the disc to which they are directly or indirectly attached; *g* the variable pulley covered with leather and resting upon the lower disc *a*, and itself pressed upon by the weight of disc *b*; it is thus driven at speeds varying according to its approach to or from the shaft *d*, thus answering the purpose of the traversing leather belt of the cone movement; *h* shaft keyed in the pulley *g*, from which the variable motion is transferred to the bobbins.

619



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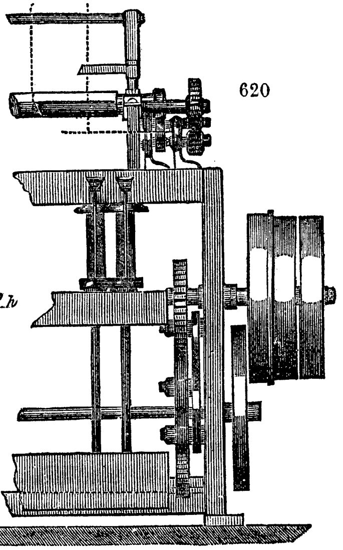
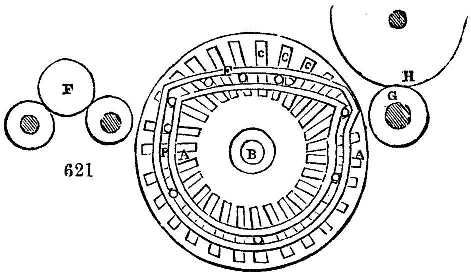


A series of preparing machines, termed a "system," consists in general of 1 spreading of 4 slivers at the drawing rollers, united into one by the doubling bars at the delivering roller, 2 frames of second drawing, in all 24 bosses 2 frames, third drawing containing together 36 bosses: if a fourth drawing is required, 2 frames of 24 bosses each, or 48 bosses in all. 180 spindles of roving in 3 frames will well supply 3000 spindles of medium spinning. The mode of using this "system" is, as has already been said, first to spread the stacks of line upon the feeding-sheet of the "spreader," then to receive the sliver or slivers there produced into cans capable of holding 1,000 to 1,200 yards of slivers. Those cans specially intended to receive the slivers from this machine are all made to one regular weight; thus, when filled, the weight of line each contains is correctly ascertained, and by the bell motion the length is also known. Upon this basis is founded the method of producing any desired number of yarn, and by doubling the slivers, a degree of equalisation that the simple spreading would be unable to effect, for at each drawing and at the roving several of the slivers from the preceding drawing are put together, to be again reduced to one for this object alone. Hence, the weight of a determinate length in yards of the desired yarn being known, a calculation is made, combined of the drafts and number of doublings the material has to undergo, to determine what the weight should be of that length of slivers contained in the cans from the spreader. It is ordinary to put 10 or 15 of these "cans" together, to form what is called a "set," the slivers of which are united at the second drawing with the subsequent drawings and rovings: the combination of two or three slivers at each boss is sufficient.

Though the above is descriptive of the "gill" frames now in use, yet it should be understood they are by no means the first or only results of the attempts made to correct the defective principle of the original roller machines, which were incapable of holding or retaining the flax with a sufficient degree of regularity, owing to its unequal length and unadhesive nature. The consequences were that the yarns produced were "lumpy" and unlevel, making it evident that some improved means were necessary for more completely restraining and regulating the drawing of the fibres. The most obvious way to do this was to introduce some mode of partial detention by creating a friction among the fibres to imitate the action of the fingers in hand-spinning. This led to causing the slivers to pass through and among several ranks of serrated pins, which was found very nearly to attain the object, and certainly greatly improved the levelness and uniformity of the slivers. Thus the use of "gills" became general about thirty years since.

Those first brought into general use were constructed with circular discs or plates for carrying the faller or gill bar, which at the same time were guided by their ends passing in fixed slides so as to bring the gill in as vertical a position and as near the drawing roller as possible. The figures (621,622.) are profile and front views of the working parts of one of these gills:—A, slotted plate or disc, of which a pair were keyed upon a shaft B, so as to carry each end of the faller, D, passing through the slots *c, c;* E the fixed excentric slide; G, H the drawing rollers; E the holding rollers.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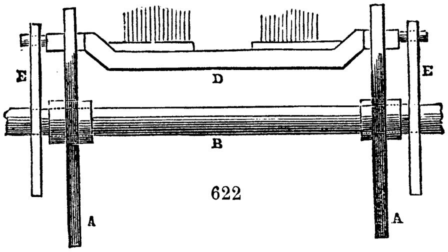
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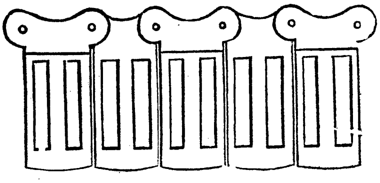
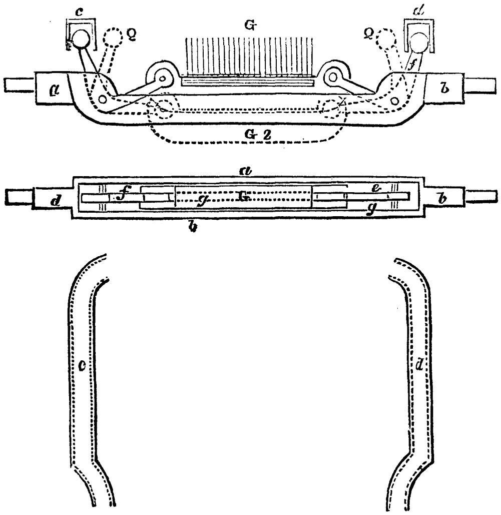
This was succeeded by the "chain gill," in which the fallers were carried forward by an endless series of connected links, or jointed together "slotted plates," instead of the simple circular. The object of this was to increase the flat surface of gill bars between the holding and drawing rollers, making it more suitable for the longer descriptions of material. The slides and rollers, being similar in these machines to those in the former, are not repeated, but the sketch of five slotted plates is given in *fig.* 623


623

From the evident importance of bringing the retaining effects of the gills as closely as possible to the point where the movement of the drawing fibres is greatest, several attempts have been made to improve the above described gills in this respect. With this view Messrs. Taylors & Wordsworth patented a gill of considerable ingenuity, (*fig.* 624.) which therefore deserves mention, though it never came into use. Its description is as follows:—

a b the faller or "gill bar" in one piece, which were carried forward by an endless chain; *c*, *d* slides placed horizontally over the gill sheet guiding the ends of certain bell-cranks *e*,*f*, jointed at their angle in the recess *f g e* of the gill bar, and at their other end to the gill or comb *g*. By this arrangement, as long as the bell-cranks are in the parallel parts of the slides *c*, *d*, the gill teeth will be above the faller *a b*, but when they arrive at the contracted part the guided ends will be brought into the position Q Q, and consequently the gill depressed is G 2; this is so timed as to cause them to clear the drawing roller, when, on again continuing their course, they are again caused to rise and penetrate the sliver by the reversed inclination of the slides *c*,*d* at the back roller.

The objection to this ingenious machine was the largeness of the space suddenly left open by the descent of the gill, as the double faller, bell-crank, and gill necessarily occupied a great width.



624

The screw or spiral movement of the fallers, which was soon afterwards invented, quickly superseded all others in use, as by these means the faller was caused, even in the

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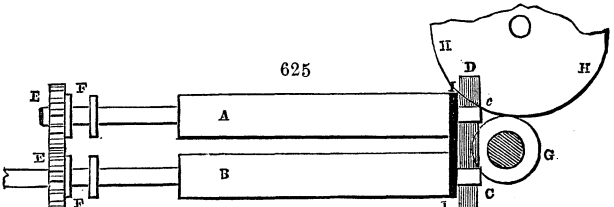

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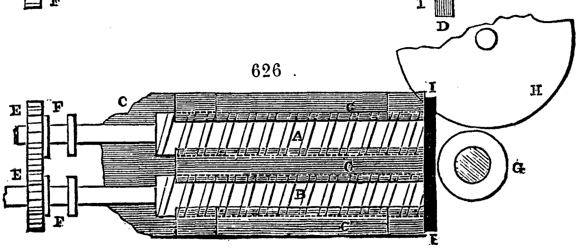
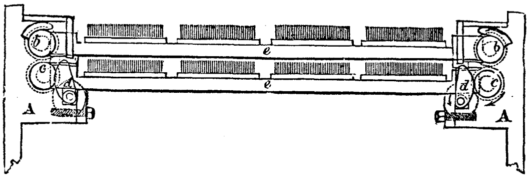


manner they were first constructed, to approach closer than even in the most perfected construction of the others, to the side of the drawing roller, and still maintain the pins in a vertical position. Recently this object has been more perfectly attained by a patented improved construction adopted by Messrs. P. Fairbairn & Co., whereby the obstacle to the faller wholly touching the roller has been removed, and thus producing the full holding effect of the gill to the latest possible moment. This is effected by employing a method of supporting the spirals by their working in tubular recesses in the side plate of the machine; along these recesses are longitudinal openings through which the faller end passes to enter between the threads of the spiral, and which serve also as slides to support the faller. As by this means the supports or plummet blocks that intervened between the end of the spirals and the roller are suppressed, the faller is enabled to advance to the place they formerly occupied. *Fig.* 625. and 626. show this comparison of the older and more recent methods. A, B spirals; C, C the parts by which they are supported, being in *fig.* 625. small pivots in plummet block D D, and in *fig.* 626. hollow tube-like recesses in frame plate C C; E, E pinions to work the upper and lower spiral together; F bearings; G drawing-rollers; H pressing-rollers; I I passage of the faller's descent.

Here it may be as well to observe that the same parties have still more lately introduced another important amelioration in these machines for remedying the noise and wear and tear which ordinarily attend them by the abrupt and violent descent of the faller. *Fig.* 627. shows a sectional front view of a head having this improvement



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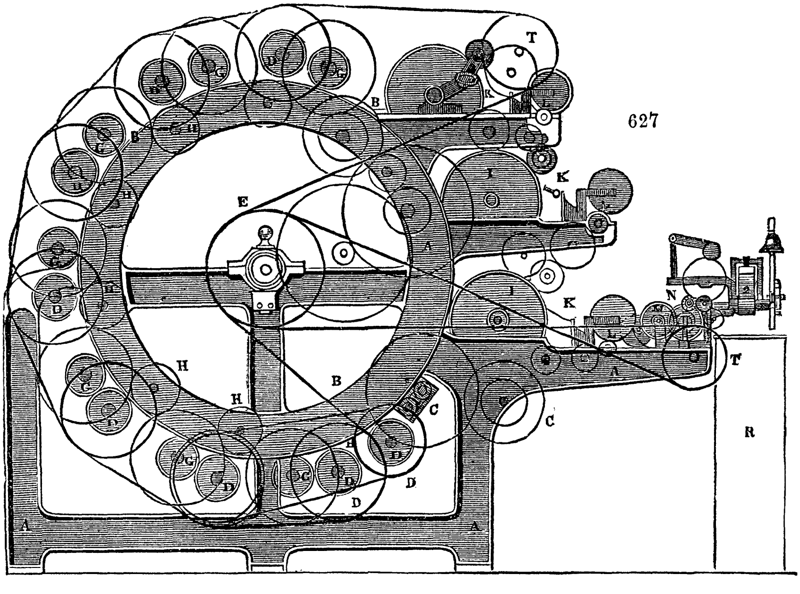
applied. A A supports for screws; *b*, *c* top and bottom screws; *d*, *d*, the new cams fixed on shafts parallel with the screws, and revolving at the same speed. Thus, these cams *d*, *d* receive the faller *e e* at their largest diameter, at the moment they are free to descend, and guide them gradually down to the lower slide.

Thus constructed, the "screw gill" continues to be the most esteemed in principle, though not without some serious objections in practice. For the abrupt and angular movements of the "faller" even here not only liberate too suddenly a portion of the fibres that should be but gradually relaxed at the moment of being drawn, but cause considerable wear and tear to itself, the slides, and the gills attached to it; to which cause of destruction must be added the great friction of the worm movement; these, however, in "line" preparing, where the fibres are long and straight, and the drafts employed large, and where, consequently, a comparatively slow movement of the gills is required, are not so much felt as in the preparation of tow, where they become serious.

In "tow preparing" the first operation, as before stated, consists of "carding," which is generally repeated over two separate machines, which are respectively called the 'breaker" and the "finisher" cards. They are essentially the same in principle, and vary but little in construction, the only difference being that the "breaker" is fed or supplied by the disjointed parcels of tow from a creeping sheet (as the spreader with "line,") and delivers its slivers into a can, whereas the finisher is fed from a bobbin upon which several of the slivers from the "breaker" are united by a machine expressly for that purpose, called a "lap frame;" this card thus receives its supply of work in a very regular form, and previously to delivering it in the form of slivers causes them to pass over a gill, to consolidate and strengthen them before delivering them into the receiving can: it is also generally clothed with a finer description of wire filleting than the breaker. Though it is the better method to card thus the tow twice, yet this second carding is sometimes dispensed with; in that case this auxiliary "gill" is similarly fixed to the first card or breaker. The cards employed for tow are machines of considerable weight and importance, the main cylinder, or, as it is sometimes called, "swift," being from 4 to 5 feet diameter and 4 to 8 feet long; those most generally employed are 6 feet long. Previously to entering upon the detailed description of a card, it may be as well first to trace in general terms the progress of its operations, as tending to elucidate the explanation of the machine itself.

The tow is first divided by weighing into small parcels of 10 to 20 drachms; these are then shaken out and spread so as to cover certain definite portions of the creeping feeding sheet, by which they are conducted to the first pair of rollers called the feeders. These rollers are covered with a leather band, in which are fixed in close array a number of wire points about ½ an inch long, and having a tangential inclination to the circumference of the rollers, which are about 2½ inches diameter. The tow, passing at a slow rate of progression between these rollers, is by them gradually presented to the points with which the swift is likewise covered, also set in leather bands, but which are about 2 inches wide; these points, the same length as those of the feeders, have an inclined direction pointing to that in which the cylinder turns. The much greater velocity of the " cylinder" combs and somewhat opens and breaks the tow as it slowly arrives in contact, and the inclination of the pins at the same time carries it forward. All such lumps and fibres as are not sufficiently opened and straightened by this first contact, remaining prominent on the surface of points on the cylinder, are carried by it against another roller, whose axis is parallel, and whose wire-covered circumference is brought as near as possible, without absolute contact, in order to catch and retain these prominent lumps and fibres; the points of this roller (called a "worker") are inclined in a direction opposed to the movement of the swift, and, therefore, hold the "tow" to be again combed and straightened as at first it was by the feeders: this is repeated eight or nine times, by having that number of workers to the card; each of these workers has its attendant roller, also covered with wire points, by whose inclination in a contrary direction, and by the greater velocity of the roller, the tow is stripped from the workers, to be again laid on to the cylinder. The strippers, though running at a greater velocity than the workers, are still slower than the cylinder. The tow thus carried forward gradually improving in openness and regularity as it passes each pair of " workers and strippers," finally arrives at the roller called a doffer, of which there are two or three upon a card, the wire points of which are in such a direction as to hook or catch the "tow" "as it flies." The use of these several doffers is, that by placing each succeeding one progressively nearer the swift, the longer and shorter fibres are successively and separately taken off. Each doffer is cleared by an oscillating comb, and the slivers conducted, if intended for the lap machine, into a can by delivering rollers; but if finished, these delivering rollers are as it were the back rollers of the auxiliary gill, patented for this application by Messrs. Fairbairn and Co.; whereby the slivers are not only saved from all danger of derangement in their loose and porous state as direct from a card, but the hitherto double expense of carding, and first drawing is reduced to that of carding alone.

A A A, (*fig.* 627.) framing; B, swift or main cylinder; C, feed rollers, D, D, D, strippers to feed rollers and workers driven by one belt from pulley E, and maintained tight by the



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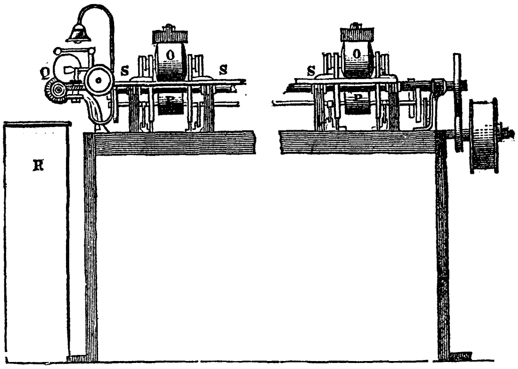
movable pulley F; G, G, G, workers; I, I, I, the three doffers; H, H, H, intermediate wheels to connect the movement of the doffers with one another; K, K, K, oscillating combs for their respective doffers; L, delivering rollers: M, back roller of auxiliary gill; N, gill **surface**; *o*, *p*, drawing rollers; Q, delivering rollers and bell motion for measuring the



629

slivers into the cans R; S S, doubling plate; T, pulley for driving auxiliary gills by bell from the pulley E.

The lap frame to which allusion has already been made as the necessary adjunct to the cards when double carding is to be performed, is employed to collect together a number of slivers from the "breaker" by winding or lapping them upon a cylindrical piece of wood, which may be described as a bobbin shank, thus producing an equalisation of the slivers of tow as the making up of sets effected in line preparing; from 50 to 60lbs. of tow is the usual complement of one of these bobbins, the length and the diameter, when full, about 22 inches; thus, a 6 feet wide finisher card will take off these bobbins at once; from 15 to 20 is the number of slivers usually wound together, and the completion of a bobbin by the ringing of a bell, connected with the measuring cylinder of the machine. The following is a descriptive drawing of the lap machine.

A A A, (*fig.* 630. & 631.) framing; B, measuring and pressing cylinder; C, C, C, driving pulleys connected with different geering to change the speed as the bobbins fill; D, bobbin or shank intended to be filled; E, table to receive the bobbin when about to be taken from the machine; F, weight to increase the effect of pressure of the measuring cylinder by the connecting rods G, G, G, which are split for part of their length in order to pass the shaft H, and at another *gg* have racks into which work pinions keyed on the shaft of

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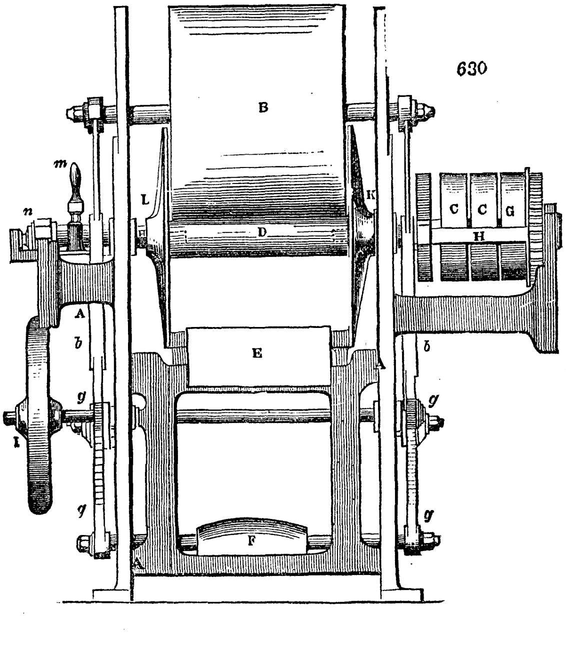
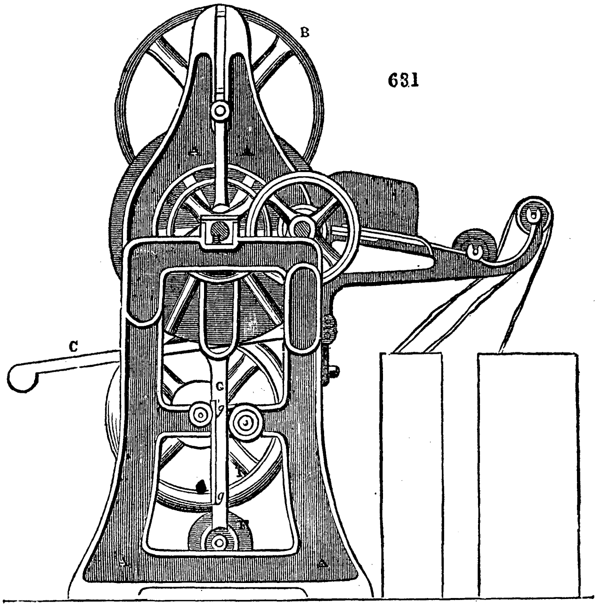


the hand wheel I, for the convenience of raising and lowering the cylinder and weight. The shaft H is divided at the plates K and L., and provided with sockets to receive the end of the bobbin shank B, which is introduced by sliding back the piece H *n*, and returning it by lever *m*, and thus is coupled and turns together with two pieces of shaft H, as also the disc plates K and L, which are to serve as temporary ends to the bobbin during the time of its filling, and thus by turning with it avoid that rubbing and felting effect upon the edges of the tow so injurious in the machines formerly constructed and by the bobbin acting as the driver to the cylinder the slivers are drawn tighter, and thereby avoid those plaites that the other machines were so liable to produce.



631

As before mentioned, some objections were found to the working of the screw-gill, of a nature detrimental to the machines themselves, which, though not of great importance in "line," were much aggravated in tow preparing, as the lesser drafts there employed cause a greater wear and tear of the fallers and gills. The objection to these machines, however, is not confined to this point only, but extends also to their effect upon the material itself. The fibres of the tow sliver, as coming from the cad, are in a light and much confused state, which renders them liable to be easily separated; so that the faller, by its sudden descent, has a tendency to draw some down, and become lapped by them, as well as to make so marked a difference in the thickness of the sliver, by the withdrawal of the retaining comb, as materially to injure the quality of the yarn. Thus this "gill" was not enabled to hold its place in tow spinning, when other circumstances led to greater attention being paid to this important branch of the flax business, and it became a desideratum to have a machine free from these defects, and capable of working without derangement, at much greater velocity than was safe with the "screw-gill." These desiderata the "rotary" gill, patented by Messrs. Fairbairn & Co., amply supplies. For in this gill the circular form of the gill sheet obviates the necessity of having several fallers, and the simple motion creates neither friction nor abruptness of effect, while the retention of the fibres being continuous, the slivers produced are perfectly level and uniform, consequently these gills are extensively applied, as the auxiliary gill explained in carding, as well as for the subsequent drawings and rovings of tow, and sometimes, as will be afterwards seen, to coarse spinning. The theoretical construction of these rotary gills will be seen by the annexed sketch.

M, (*fig.* 632.) back rollers, but when applied to a card at top and bottom holding rollers are again employed; N, the rotary gill sheet having the pins inclined backwards, so as to insure the impalement of the sliver when the fibres begin to draw: P and O, the drawing and pressing rollers; the doubling bars or plates are the same to these gills as to the "screw-gills."

Subsequently to the carding the preparation of tow is completed by making up sets

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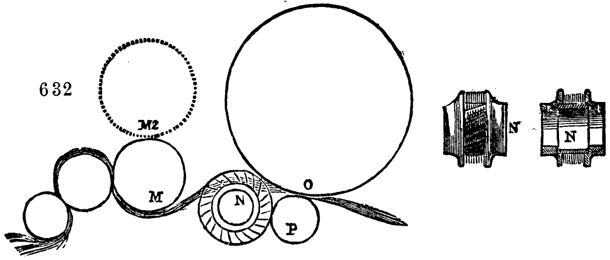

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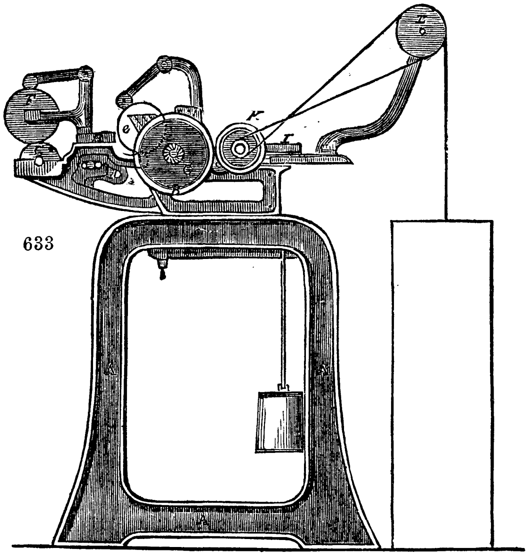


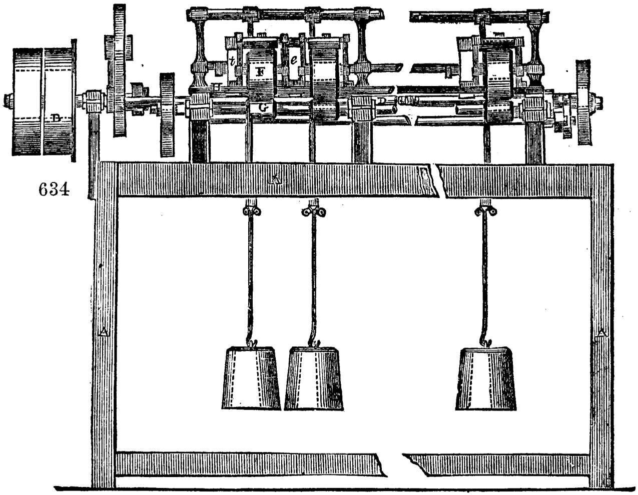
of cans for the second drawing, as explained for line; these slivers are doubled and drawn once or twice more, and then roved. The drafts used in tow preparing are from 6 to 8, for as the fibres are shorter, it necessitates the employment of less draft. In both line and tow preparing, lesser drafts are employed as the stages advance, the gills finer, and the conductors narrower; also for both materials much attention is requisite to keep the various parts of the machines in good order, free from bent or broken pins, and chipped or indented rollers, for no subsequent operation can cure the defects that may be produced by negligence in these particulars. The drawing and roving frames for tow are shown in *figs.* 633, 634, 635.

A A, (*fig.* 634.) drawing framing; B, driving pulleys; C, rotary gill sheet; D, drawing roller; E pressing; F, G, pairs of delivering rollers; A, doubling plate; I, back conductor; K back roller wheel with pulley to turn the sliver rail I.

A A, (*fig.* 634 & 635.) roving frame; B, pulley and fly wheel combined; C, drawing roller: D, rotary gill; *a a*, stand for gill movement. The regulation of the bobbins is effected in the same manner as already described for line roving.

5th. *Spinning.*—This operation consists in drawing the "rovings" down to the last degree of tenuity desired, and twisting them into hard cylindrical cords, which are called "yarns."

There are three modes of performing this operation; the first, and perhaps oldest, is that where the drawing and twisting are performed altogether, with the material preserved dry, and without breaking or shortening the fibre; the second is that which likewise, without changing the length of the fibres, draws them while dry, but wets them just at the moment before twisting. This method is the nearest imitation of hand spinning, and makes the yarn more solid and wiry than the first; as the fibres of flax losing their elasticity while wet, unite and incorporate better with one another. The third mode of spinning has been much more recently introduced than either of



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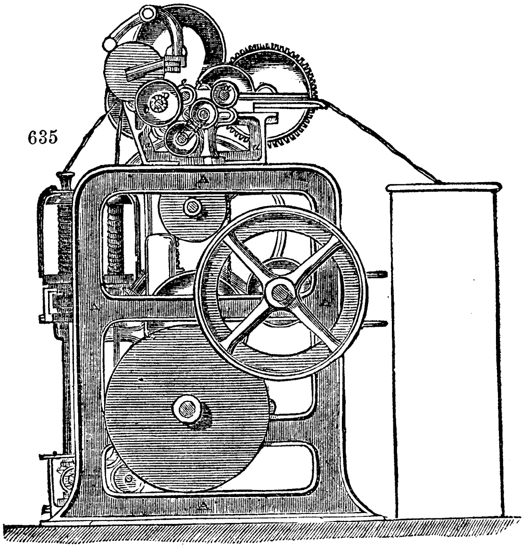

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the others, and by it the fibres are wetted to saturation previously to being drawn, whereby they are not only much reduced in length, but their degree of fineness is increased by the partial solution of the gummy matter, inherent in the flaxen material: owing to these circumstances equally good yarns can be produced by this mode of spinning from line and tow of inferior quality, to what could be employed upon either of the others, and not only that, but much finer yarns can be now spun than were possible previous to its introduction. It has therefore not only nearly superseded all other methods of spinning for yarns from 20's to the finest, but has much increased the extent and importance of the flax manufacture.

The only difference in spinning frames for "line or tow," when employed for the older methods, consists in the length of reach, which generally involves the necessity of having separate machines for each material, though sometimes they are made with a capacity to be adapted to either purpose. In the third method the same machines were used promiscuously for "line or tow."

The yarns spun wholly dry are used for the coarse description of woven goods, as packing canvass corn sacks, and when partially bleached for sheetings and towellings as from its greater elasticity and openness it fills up better in weaving. Those spun partially wetted are employed for a somewhat superior description of linen goods, and the solid silky appearance qualifies them for drills, damasks, &c., as well as for sewing and shoe threads; a somewhat inferior material, by this manner of treatment, makes an equally good yarn as a better material spun dry. The yarn produced from this wet principle is rather inclined to have a cottony appearance, and from the comparative ease with which an inferior material can be made to represent an apparently fine good yarn, the application of yarns thus produced is exceedingly various and sometimes deceptive, though when good materials are used, these yarns afford durable and handsome drills, shirtings, lawns, and cambrics, as well as fine sewing threads.

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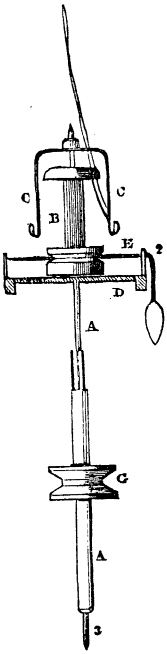


The mechanical arrangement for twisting, and then winding the yarn upon a bobbin, is called the "throstle" principle, supposed to be so called from the whistling noise they create when working at full speed, which is from 2,500 to 4,000 revolutions a minute. The following diagram will explain the principle, which is applied alike to all the modes of spinning above described.

A A, (*fig.* 636.) the spindle; B, the bobbin, loose and independent of the spindle in regard to turning, and rising, and lowering, but through which the spindle passes; C C, the flyer screwed to the spindle top; D, table called bobbin lifter, as while at work it rises and lowers to lay the yarn on the whole bobbin equally; E, a small cord to press on the bobbin by the weight F; G, pulley by which the spindle is driven.

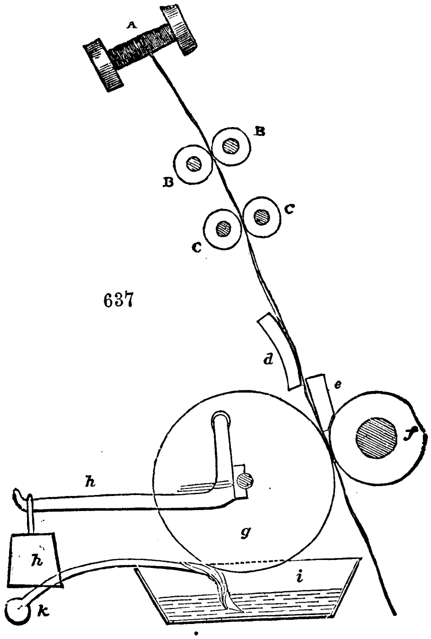
Many attempts have been made to improve upon this principle, in order to avoid or lessen the strain upon the thread in its passage from the drawing rollers to the flyer eye; but, till recently, without any degree of success. The only improvement at present known, and which promises to become general, is that where the necessity to have a top to the bobbin is avoided. It will be seen from the above diagram, that the yarn is compelled to rub the top of the bobbin, and the friction thereby created quickly causes it to become rough; and therefore it has a tendency to catch and break the thread. The desirableness, therefore, of having a clear course for the yarn was evident, and this improvement that we are about to explain produces the effect by employing what is called a coping motion, which, like that used in mule spinning, preserves the layers of thread upon the bobbin ever in a pointed or conical state, and therefore self-supporting without the aid of the wooden end of the bobbin. See COTTON SPINNING.

The arrangement of the rollers for holding and drawing the slivers or rovings, as well as the plates and rollers for aiding to retain the twist of the rovings, in order to render their elongation more equable when to be drawn dry and spun upon the older methods, will be seen in *fig.* 637.

A, (*fig.* 637.) roving bobbin; B, back or holding roller; C, carrying roller, *d* flat plate with a slightly curved face; the carrying roller and plate are so placed as to cause a degree of friction to the roving when passing over them, so as to retain the twist, and thus act as the pins in the "gill frames;" *e*, tin conductor for contracting the roving at the moment of being drawn; *f*, metal roller; *g*, wooden roller pressed against the drawing roller in order to pinch the roving; *h*, lever and weight. When it is intended to wet the yarn previously to twisting, the trough *i* is used, in which is water, which is supplied to the roller *g* by the capillary attraction of a piece of cloth immersed therein, and bearing against the roller by lever *k*.

The machines for "wet" spinning are of a very different construction and appearance; as the close proximity of the holding and drawing rollers prevents the intervention of holding rollers or friction bars, while the force requisite to draw the rovings at the short reaches used, varying from 2½ to 4 inches, requires each pair to be deeply and accurately fluted into one another. The water used is heated, in order by the expulsion of the fixed air more rapidly and completely to saturate the rovings while passing through it. The following drawings and description will be sufficient to give an accurate idea of the principle of these machines, which are generally 20 to 30 feet in length, and contain 200 to nearly 300 spindles; that is, 100 to 150 on each side.

A A A A, (*fig.* 638. & 639.) framing; B B, stand for roving bobbins; C, driving pulleys fixed upon the axle of cylinder D, from which pass endless cords to drive the spindles



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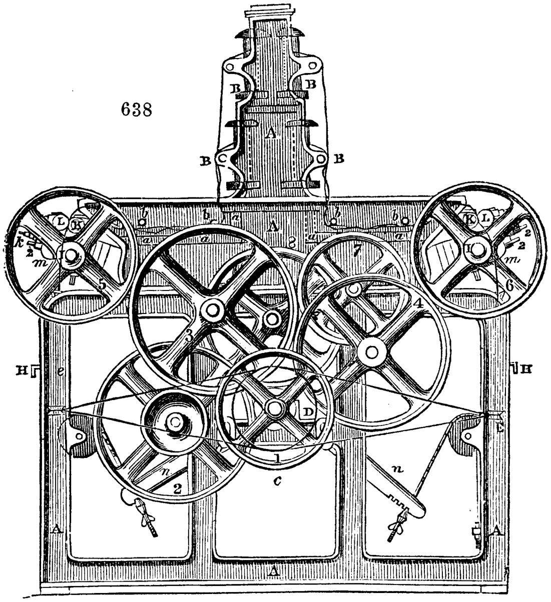

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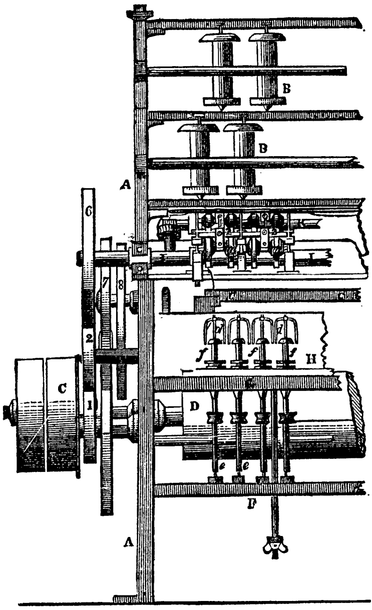
e e; F, step rail of spindles; G, collar rail for ditto; H, bobbin lifter; I I, front roller; K K, back roller; L, back pressing roller; M, top pressing roller (these are generally made of box wood, but sometimes of gutta percha); N, N, levers in connection with the excentric to produce the rise and fall of the bobbin lifter; O O, thread plate; Q, Q, saddles or transverse bars resting on the axles of the back and front pressing rollers,so that one lever and weight acts for both by the connecting rod to lever *r r*, which, in order to cause more pressure on the drawing than on the back roller, is placed on the saddle nearer the former than the latter. 1, 2, 3, 4, 5, 6, 7, 8, train of wheelwork, by which the movements are dis



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tributed. *a, a, a,* the trough of hot water maintained by steam-pipes at the desired temperature; *b, b,* guide rods or pipes to cause the roving to pass under the water. In order to avoid the rollers becoming indented by the roving always passing on the same place, they are caused to traverse the breadth of the rollers by a traversing guide rail, moved by an excentric at the worm and wheel *c*; *d,* flyers, and *f,* spindles.

Here it may be proper to introduce a description of the machines for twisting the yarns when spun into "threads" used for sewing, &c. The yarns spun for this purpose should always be made of a somewhat superior description of line to that employed for the same number of yarns for weaving, and have rather less twist. They are generally taken while wet on the spinning bobbins to the twisting frame, and, when combined together, the union is effected by a torsion in the opposite direction to the original twist of the separate yarns.

6. *Reeling.* — This operation consists in winding the yarn off the bobbins of the spinning or twisting frames, and forming it into hanks or skeins. The various denominations of the skeins into which yarn is reeled, and then the forms or combinations they are made up into, are as follows:—

The lea containing 300 yards
10 leas making 1 hank
20 hanks „ 1 bundle
6 bundles „ 1 packet.

It is by the standard lea of 300 yards that the description of yarn is known from the number contained in 1 lb. weight; thus No. 20. contains 20 leas or 6000 yards for 1 lb weight. In Scotland, the subdivisions are rather different from the foregoing, which are employed in England and Ireland; the lea, however, remaining the same:—

38 leas make 1 spindle
6 „ 1 rand
12 rands „ 1 dozen.

The reeling is peformed upon exceedingly simple machines, generally put in motion by the hand of the person attending them, though sometimes they are driven by the motive power of the factory. The reel is made sufficiently long to receive twenty bobbins, and the barrel upon the yarn is found in one length; the diameter, however, varies so as to suit the different-sized yarns to be reeled. For the coarsest yarns and down to 16. and 20., the largest circumference is used of 3 yards, from that to about No. 100. 2½ yards, and for the finest yarn 1½ yards is found most convenient. These various circumferences are compensated either by putting a great number of threads into each "tye," or increasing the number of tyes, so that opposite to each one of the 20 bobbins an entire hank should be formed before taking the yarn off; thus at each "stripping," one bundle is turned off. To facilitate the stripping, one of the rails of the barrel is made to fall in, and thus slacken the hanks; care is taken to leave the leas bands very loose, in order to allow the yarn to be spread out in drying and bleaching. The determinate lengths of yarn, when wound on the reel, are notified by the ringing of a bell connected with the axle of the barrel. Figure below shows the form of an ordinary hand-reel.

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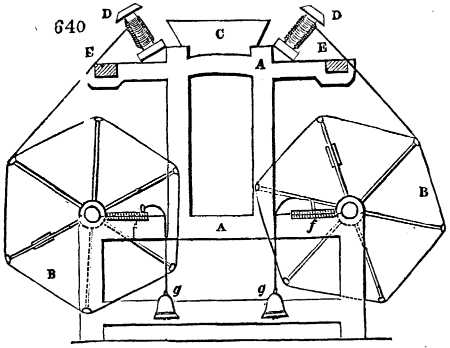


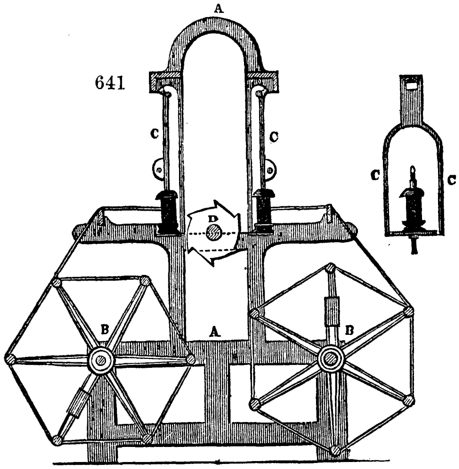
A A (*fig.* 640.) framing; B B reel barrels; C box or trough to receive empty bobbins, &c.; D D bobbins in position of being reeled; E E guide rails moveable so as to place the leas side by side on the reel; *f f* bell wheels; *g g* bells for each reel barrel suspended on springs.

To these hand-reels there are many objections; for it is evident that the correctness of measure depends entirely upon the attention of the reeler, and the stoppages arising from the breaking of a thread or the finishing of a bobbin interrupt the work of all the others. These objections rendered it necessary to attempt some ameliorations of the system by the introduction of a reel that should automatically prevent these causes of error. Such a reel was patented a few years since, and is now in general use in Scotland; it is so contrived as to have the capacity of stopping itself when a thread breaks, when a bobbin finishes, and leas and hanks completed; and having but four or five bobbins in one compartment, the stoppages affect but few at a time; and as this machine can be worked by less skilful persons without possibility of error, much saving is effected both in wages and material. The annexed figure (641.) shows the principle of this improved reel.

A A (*fig* 641.) framing; B reels; C, C pendulums on which are hung the bobbins to be wound off; D driving shaft with ratchet wheels opposite to each pendulum, so that when a thread breaks, the pendulum to which it was attached falls into the ratchet wheel, and thus stops it.

The drying of wet spun yarns should always, when possible, be done in the open air by spreading the hanks upon horizontal poles through them, with another similar pole resting inside upon their lower extremities, in order to keep them straight. If artificial heat is employed, that from steam or hot water is preferable, and it should never exceed 90° Fahr., as otherwise the yarn is apt to become harsh.

641



7. *Making up.*—By this operation is first produced upon the yarns a certain softness and suppleness, and then the hanks are folded and tied up in conveniently-sized packages.

In order to give the yarns that soft and mellow feel so agreeable and characteristic of flax yarns, the hanks, when brought from the drying, are what is called shaken down and pin-worked. This is done by separating a few at a time, and passing them on to a strong arm of wood fixed to a wall or pillar, when with a heavy baton put through them, the workman proceeds to stretch the hanks with a sudden check or jerk, which operation he repeats in two or three places so as to thoroughly straighten and shake them loose; he then, using the same baton as a lever, twists them lightly backwards and forwards till the desired degree of suppleness is obtained. A brush is sometimes used to aid the straightening and separating, as well as to increase the gloss on the yarn. · The hank or hanks will then be found to have assumed a flat shape, as on the reel, which facilitates their folding with a dexterous twist by their middle, when they are laid in square piles upon a table with their twisted folds one upon another. They are maintained in the perpendicular by a few supports fixed in the table. Sometimes these packages, which, according to the sizes of the yarn, consist of from ½ of a bundle to 5 or 6 bundles, are bound together by some of their own hanks, but sometimes by cords in three or four places of their length. It is, however, better to employ a bundling press than an ordinary table, as the yarn can then be made up more solidly, thus both improving its appearance, and causing it to occupy less space for packing and stowage. The bundling presses are made upon the same principle, but on a smaller scale, for making up the small packets, in which sewing threads are generally presented for sale, and are upon the following construction, (*figs.* 642, 643).

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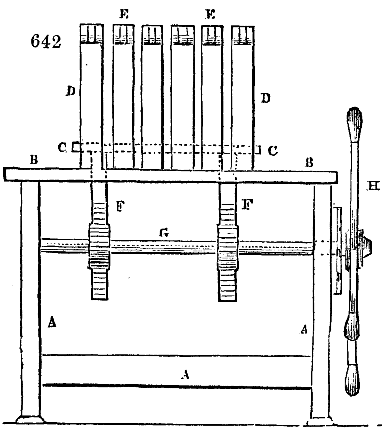

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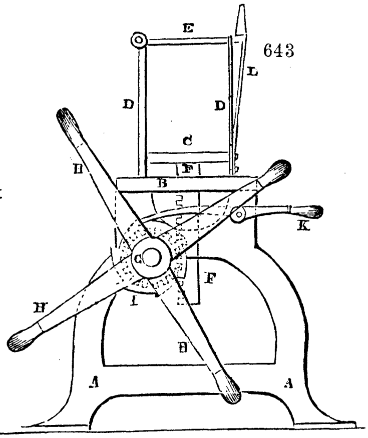

Fig. 642. front view; *Fig.* 643. profile. A A A frame; B table or flat top of frame; C rising table; D D iron uprights fixed to B; E E bars hinged at one end to uprights D D, to shut across the press, and be caught and latched down by the spring catch L fixed to the upright D along one side of the press; F F racks for lifting the table C by the pinions on shaft G; H crossed levers for turning the shaft G; I ratchet wheel engaging the detent K, and thus retaining the shaft G in any required position, and thus of course maintaining the pressure of table C against the top cross-bars E.

8. *Weaving,* is the operation by which the yarns are combined into textile fabrics, such as canvas, linen, drills, damasks, &c., and a great variety of other denominations of article for use and ornament.

Hitherto the weaving of linens has been carried on by the ancient and well known hand process, so ancient and so well known as to place the operative practising it among the worst paid of any other art. Now, however, there are several extensive and thriving establishments, where machinery has taken the place of much squalid misery, and at much cheaper rates produces to consumers superior articles, and still affords good payment to the operative. The improvements in power weaving which have led to this result are not founded upon one or even a few successful inventions or contrivances, but are the combination of a great many that have occupied much time to mature. Many difficulties had to be overcome in the weaving of flax that did not exist in that of other materials; and for a considerable period the expense of linens rendered their consumption so limited, as to make their production by power weaving but a very secondary object. The greatest obstacle of a practical nature to the introduction of the automatic weaving of linens was, the stubbornness or want of elasticity in the yarn, which caused frequent breakages, and much confusion. In woollen or cotton goods, if a thread or yarn should chance to be a little tighter than the others in the warp, its elasticity will allow it to come up to the general bearing of the others when the weft is struck up by the reed; but in linen, from the want of that elasticity, a thread so situated would break, and by crossing some others cause them, if not to be broken direct by that circumstance, at all events cause an obstruction to the shuttle that would lead to further mischief. Hence it was most material in linens to have such a method of winding the yarns upon the warp beams that should insure the greatest regularity; but strange to say, that point, though now attained, was at first wholly lost sight of. That circumstance, as well as the great mistake of attempting to use the same looms as are found suitable for cotton, produced so much discouragement in the earlier attempts as to give rise to a high degree of prejudice against the possibility of success in this undertaking, which may account for the backwardness in which this branch of the flax manufacture was found till quite recently. See article Flax Weaving Loom.

The new roving machine, called by the ingenious inventor, Mr. W. K. Westley, of Leeds, the Sliver Roving Frame, seems to be a *philosophical induction* happily drawn from the nature of the material itself, and accommodated to its peculiar constitution. It is remarkable for the simplicity of its construction, and, at the same time, for its comprehensiveness; requiring no nicety of adjustment in its application, and no tedious apprenticeship to be able to work it.

It is known, that the glutinous matter of the plant may be softened by water, and hardened again by heat; of this fact advantage is taken, in order to produce a roving wholly without twist; that is, in the form of a ribbon or sliver, in which the fibres are held together by the glutinous matter which may be natural to them; or which may, for that purpose, be artificially applied. The sliver roving, as long as it remains dry, possesses all requisite tenacity, and freely unwinds from the bobbin, but on becoming again wetted in the spinning frame, it readily admits, with a slight force, of being drawn into yarn, preserving the fibres quite parallel.

The diagram, *fig.* 644., shows in explanation, that

A, is the drawing roller of the roving frame in front of the usual comb.
B, the pressing drawing roller.
C, a shallow trough of water.
D, a cylinder heated by steam.
E, a plain iron roller for winding.
F, a bobbin lying loose upon the winding roller, and revolving upon it, by the friction of its own weight.

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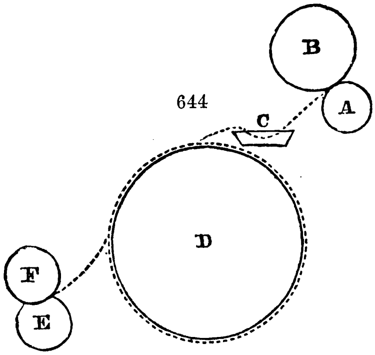

The roving, or sliver, as shown by the dotted line, after leaving the drawing rollers, A, B, passes through the water, in the trough C, which softens the gluten of the fibres; and then it is carried round by the steam cylinder D, which dries it, and delivers it hard and tenacious to the bobbin F, on which it is wound by the action of the roller E.

This is the whole of the mechanism required in producing the sliver roving. All the complex arrangements of the common cone roving are superseded, and the machine at once becomes incomparably more durable, and easier to manage; requiring only half the motive power, and occupying only half the room. A frame of 48 bobbins is only 6 feet long, and affords rovings sufficient to supply 1200 spinning spindles.

This machine, though here described, is but little used, being capable of but very limited application.

The following sketch shows the arrangement of the machinery in the most important rooms in a modern flax mill of 7000 to 8000 spindles, capable of producing, weekly, about 1900 bundles of line yarn, No. 25.'s to 120.'s; and about 700 bundles of tow yarn, No. 10.'s to 40.'s.

There are three systems of long line machinery for No. 25.'s to 70.'s; two systems of

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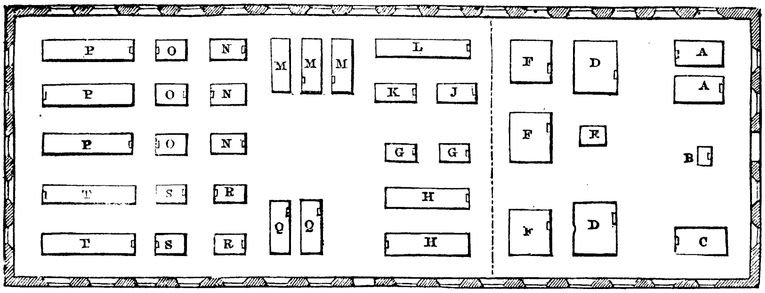

cut line machinery for No. 10.'s to 120.'s; and three systems of tow machinery for No. 10.'s to 40.'s.

The building is 56 feet wide and 162 feet long; which is a very suitable and convenient size, and which admits of the most economical arrangement of the machinery.

The following is a description of the machines shown in the preparing room:—

A, A, two of Baxter's patent sheet hackling machines for long tow.

B, a flax-cutting machine.

C, one of P. Fairbairn & Co.'s patent double line of holder hackling machines for cut line.

D, D, are two breaker cards 4 feet diameter × 6 feet wide.

E, lap machine.

F, F, F, are three finisher cards 4 feet diameter × 6 feet wide, with P. Fairbairn & Co.'s patent rotary gill drawing heads attached.

G, G, are two patent rotary gill drawing frames for long tow, 12 slivers each.

H, H, two ditto regulating roving frames 48 spindles each for long tow.

I, is a screw gill second drawing frame of 3 heads for cut line tow.

K, is a screw gill third drawing frame of 3 heads for cut line tow.

L, a screw gill regulating roving frame of 72 spindles for cut line tow.

M, M, M, are three long line first drawing frames or spreaders of 4 bosses each.

N, N, N, are three long line second drawing frames of 2 heads each.

O, O, O, are three long line third drawing frames of 2 heads each.

P, P, H, three long line regulating roving frames 60 spindles each.

Q, Q, are two cut line spreaders of 4 bosses each.

R, R, two cut line second drawing frames 2 heads each.

S, S, two cut line third drawing frames 2 heads each.

N, T, two cut line regulating roving frames 72 spindles each.

The spinning room contains 34 spinning frames of 184 to 244 spindles each, apportioned to the several systems as described below.

I. System of long line machinery for spinning No. 25.'s to 40.'s.

1 Baxter's patent sheet hackling machine, 6 tools.
1 spreading or first drawing frame, 4 bosses.
1 second drawing frame, 2 heads 4 bosses each.
1 third drawing frame, 2 heads 6 bosses each.
1 patent disc regulating roving frame 60 spindles, 10 spindles per head, 8 inches × 4 inches bobbin.
5 spinning frames 2¾ inches pitch, 200 spindles each, 1000 spindles.

The production of this system is about 66 bundles, or say, 420 lbs. of No. 30.'s yarn per day.

II. Two systems of long line machinery for No. 40.'s. to 70.'s.

1 Baxter's patent sheet hackling machine, 8 tools.
2 spreaders or first drawing frames 4 bosses each.
2 second drawing frames, 2 heads of 6 bosses each.
2 third drawing frames, 2 heads of 8 bosses each.
2 patent disc regulating roving frames, 60 spindles each, 12 spindles per head, 6 inches × 3½ inches bobbin.
10 spinning frames, 220 spindles each, 2½ inches pitch, 2200 spindles. Production about 130 bundles, or 472 lbs. of No. 55.'s yarn per day.

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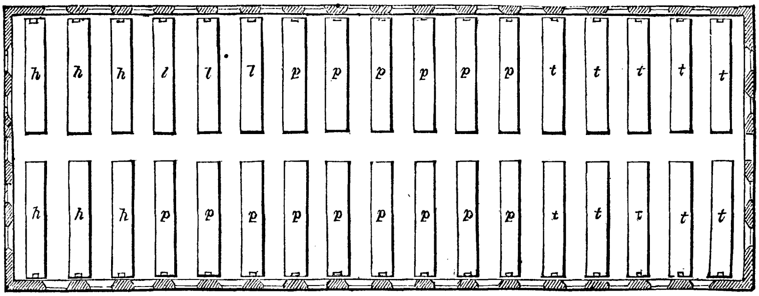

III. Two systems of three cut line machinery for No. 40.'s to 120.'s (one for 40.'s to 70.'s, and one for 70.'s to 120.'s).
1 flax cutting machine.
1 P. Fairbairn & Co.'s patent double line of holder hackling machine.
2 spreaders or first drawing frames 4 bosses each.
2 second drawing frames, 2 heads each, 6 slivers per head.
2 third drawing frames, 2 heads each, 8 slivers per head.
2 patent disc regulating roving frames, 72 spindles each, 12 spindles per head, 6 × 3½ inches bobbin.
5 spinning frames 220 spindles each, 2½ inches pitch, = 1100 spindles.
5 spinning frames 244 spindles each, 2¼ inches pitch, = 1220 spindles.
Production about 65 bundles or 236 lbs. of No. 53.'s yarn per day, and about 50 bundles or 105 lbs. of No. 95.'s yarn per day.

IV. Two systems of long tow machinery for No. 10.'s to 25.'s.
1 breaker card 4 feet diameter 6 feet wide, doffed by rollers.
1 lap machine.
2 finisher cards 4 feet × 6 feet with P. Fairbairn & Co.'s patent rotary gill drawing frames attached.
2 patent rotary gill drawing frames 12 slivers each.
2 patent rotary gill disc regulating roving frames, 48 spindles each, 8 inches × 4 inches bobbin.
3 spinning frames, 184 spindles each, 3 inches pitch for No. 10.'s to 18.'s = 552 spindles.
3 spinning frames 200 spindles each, 2¾ inches pitch for No. 16.'s to 25.'s = 600 spindles.
Production about 39 bundles, or 488 lbs. No. 16.'s per day, and about 39 bundles, or 312 lbs., No. 25.'s per day.

V. One system of cut tow machinery for No. 25.'s to 40.'s.
1 Breaker card 4 feet diameter 6 feet wide, doffed by combs.
1 Finisher card with P. Fairbairn & Co.'s patent rotary gill drawing frame attached.
1 Screw gill second drawing frame 3 heads each, 4 bosses per head.
1 Screw gill third drawing frame 3 heads each, 6 bosses per head.
1 Screw gill patent disc regulating roving frame 72 spindles, 12 spindles per head, 6 × 3½ inches bobbins.
3 spinning frames of 220 spindles each; 2¼ inches pitch, = 660 spindles.
Production about 36 bundles, or 240 lbs. of No. 30.'s per day.

The reeling is generally carried on in the attic above the spinning room, and the number of reels required is about the same as the number of spinning frames.

Summary view.

There are	3200	spindles	long line,	producing	196	bundles, or,	890	lbs. of yarn per day.
	1152	„	long tow,	„	78	„	800	„
	2320	„	3 cut line,	„	115	„	340	„
	660	„	cut tow,	„	36	„	240	„
	7332	spindles			425	bundles	2270	lbs. of yarn per day.

The waste in line spinning is generally about 10 per cent., and in tow spinning about 25 per cent., so that the quantity of raw flax required to produce the above stated quantity of yarn would be about 20 cwts. of flax for long line and long tow spinning, and about 6 cwts. of flax for cut line and cut tow spinning.

Claussen's Patent Process.—The great interest which has of late been excited in the public mind with respect to flax, in part by the enlarged sphere of application which is supposed to be opened out to it by the discoveries of Mr. Claussen, and more particularly from the fact, that it is a material of home growth, and capable of production in unlimited quantities in Ireland, would seem to demand from us special comment. We are not the less inclined to this course, as the public is ever ready to take upon trust the practicableness of any new projects, when their promised results chime in with any feeling of sympathy which happens to pervade the community; thus where the interest of Ireland is concerned, we find that commercial schemes for aiding its advancement are eagerly seized upon, and confided in almost without inquiry; but this is far from a prudent course. There can be no question that the flax trade is the growing manufacture of Ireland, and, as such, too much attention cannot be given to the production of the raw material; it has therefore been encouraged in every legitimate way, but it may be questioned whether the late announcements which have been made of its almost universal applicability to textile fabrics, will not tend to direct capital to too great an extent into this now thriving branch of industry, and thereby quickly induce a false and ruinous competition between manufacturers.

Flax, though apparently, from its fibrous character, better suited by nature than either cotton or wool to be formed into thread, nevertheless presents many difficulties to manufacturers, which are quite foreign to the working of these short staples, and which can only be in part remedied by the adoption of a somewhat different process of manufacture. In contradistinction to cotton, which may be considered the fruit of the plant, flax is the filamentous substance contained in the stalk of the plant. It has therefore to be obtained from stripping off the bark or woody coating, termed the "boon." But, in order to effect this, as well as to detach the fibres from each other, it is necessary to dissolve the gum or resinous sap, which pervades the plant, and binds the several parts together. Various plans have been suggested for attaining this end; and it is upon the efficiency of the process adopted that the ultimate success of the flax trade mainly depends. When it is understood that the growth of the flax plant is principally in the hands of small farmers without capital, and that the bulk of the flax, when reaped, is so disproportionate to the yield for manufacturing purposes as to preclude the removal of the article to any great distances in the state of straw, it will readily be seen, that no process of dissolving the gum or of "retting" as it is termed—requiring the purchase of expensive apparatus, or demanding the exercise of scientific knowledge—can be brought into general use, however efficient that process may prove to be. It cannot, therefore, be wondered at that the old plans of water-retting and dew-retting still prevail, although a far superior method, which we shall presently explain, has been introduced.

Retting is simply bringing the plant to a certain stage of decay, which causes a perfect loosening or separation of its fibres. In carrying out the water-retting process pits are dug in the ground and filled with water, and the flax is thrown in in bundles and pressed down by weighted boards, to keep it under water. After a short time, fermentation commences, and in about ten days (more or less, according to the mean temperature) the decaying process will have proceeded sufficiently far; the flax is then taken out and dried, and the boon is removed by hand. The retting may be carried on in either running or stagnant water; but the latter, although the more expeditious method, requires closer watching, to prevent the flax from losing its strength of fibre by over decay. It will be obvious that large masses of vegetable matter exposed to putrefaction must generate such exhalations as are very injurious to the health of the community. Yet this practice not only prevails, but will, as we think, necessarily increase in proportion to the increase in the growth of the plant, unless some energetic means are adopted to put down the practice. Dew-retting is a process that is less objectionable, but its operation is far slower, and it is altogether beyond the means of many farmers to adopt. In this instance the flax is strewn thinly over meadow or grass land, and then submitted to the action of the air, dews, and rain, which, in a period varying (according to the mean temperature) between three and six weeks, will effect the required disunion of the plant. This plan has an advantage over the water-retting, inasmuch as the flax is yielded of a brighter colour,—the latter process being very apt to impart a deep stain to the fibres, as well as to destroy their tenacity.

The improved plan of retting, above alluded to, was introduced into Ireland from the United States in 1847, by Mr. Schenck of New York. It had been tried there successfully on hemp; the strength of the fibre, when made into cables, having been proved in some of the government navy yards to exceed any that had been retted on the old system. The process was patented in the United Kingdom in 1846, and is now in profitable work near Belfast. A recent inspection of the factory will enable us to state in detail the manner of proceeding to separate the long fine fibres of the flax from the boon. The principal apartment in the building contains a number of large circular vats, in which the flax is steeped, and these are provided with steam-pipes connected to the steam engine boiler. The flax to be operated upon is placed in these vats and piled up to a given height; strong cross-bars of wood, forming a kind of framework, are then laid above the flax and secured to the respective vats,—the object of this framing being to keep the flax down in the vat, as otherwise it would rise as it swelled in fermenting, and protrude above the water. When a mass of flax is thus secured, water is run into the vats, and as it becomes absorbed, more water is added. Steam is now admitted into and made to circulate through the steam-pipe at the bottom of the vat, so as to raise the water to about 90° Fahr., and maintain it at that temperature. In a few hours acetous fermentation is established in the vat, and the decomposition of the resinous or gummy matter in the stalk proceeds with rapidity. After about sixty hours the decomposition is completed, and that without the exudation of any inodorous or noxious effluvium. The water surcharged with the mucilage is then drawn off, the framing is removed, and the flax is taken out of the vat to be dried, either in the open air or by artificial means. Thus, not only is the objection to the old plan, on the score of injury to health, removed, but a considerable economy in point of time is effected; the flax also is less liable to deterioration in colour and strength of fibre, if ordinary care is used in conducting the operation. When the weather is favourable for drying in the open air, the flax, tied up, in tufts or handfuls, is suspended in rows tier above tier, in an open framing, covered in at top by a penthouse roof. This mode of packing admits of a large quantity of flax being stowed in a small compass, and yet allows of a free access of air through the whole mass. When it has hung a sufficient time to dry, it is next submitted to the scutching operation. Or, instead of open air drying, the flax, in damp weather, is piled loosely in a drying chamber, into which a current of air, heated after Messrs. Davison & Symington's method, is passed, and the moisture is quickly expelled. The cost of this operation, as carried on at the works, must be very trifling, as the waste steam from the engine, which works on the high-pressure principle, is found amply sufficient for heating the air; an advantage consequent on this mode of heating is, that no carelessness on the part of the attendants will render the air liable to be heated to an extent that would injure the flax. The flax having been retted and dried, is next carried to the rolling or crushing mill, and there passed, by hand, between rotating horizontal rollers, which crack the boon already loosened by the retting process, and spread, or partially separate, the long fibres. The flax, as it is delivered out of the machine, is gathered up by boys, and handed to others, who submit it by handfuls to the action of rotating knives. These knives are attached to the face of a vertical wheel, several of which are mounted on one and the same shaft, at about three feet apart, and receive motion from the engine. There is an attendant stationed at every wheel, whose duty is to submit the flax to the action of the knives, by holding it over a fixed bar, contiguous thereto, and allowing the rotating knives to strike the flax in the direction of its length. When the boon on the half length of the flax is broken away or knocked off, the flax is turned over and the other end is subjected to similar treatment. To further clear the flax of the woody particles, it is again submitted to a similar operation before another set of wheels,—the action of the knives being, in this instance, more thorough and searching, as the flax has now approached nearer to a stick of fine fibres. Having undergone this treatment, the flax is now ready for sale in the market; and it is in this state that it enters the flax mill to be acted upon by the heckling-machine, for the removal of the tow or short staple, prior to undergoing the various operations of preparing and spinning, to convert it into yarn. From this description, it will be understood, that, so long as the cultivation of flax is in the hands of small farmers, Mr. Schenck's process is not likely to put the old practice out of use; for the water-retting is carried on at little or no outlay of money; and the cleaning of the flax by hand is made a sort of wet-day occupation: the bulk of the flax in the state of dry straw,—which, as we have before said, is so disproportionate to the amount of useful fibre as virtually to prevent its carriage to any distant part prior to undergoing the retting operation—scarcely exceeds, when carried to the market, 20 per cent. of its original weight.

M. Claussen's patented process (the merits of which have been so confidently paraded), does not seem to be in favour with the Irish flax spinners, although the specimens contained in the Exhibition appeared to the eye to realize everything that could be wished: but here, as in many other manufactures, it is not the attainment of a high degree of excellence that is the difficulty, but the cost at which such a result may be arrived at. Thus flax may be dressed from the straw, as, indeed, it was once proposed to be done, without being subjected to the retting process. The waste of material, however, soon showed the impracticability of the plan, although a good article was produced; it is possible, therefore, that M. Claussen's specimens may have been obtained without regard to cost. We do not assert this as a fact, but rather to show, that in commercial matters no just conclusions can be arrived at without the question of cost being taken into account. His mode of treating the flax will be readily understood from the following description, which we have compiled from his specification. The straw, having been stripped of its seeds, is steeped in a solution of caustic alkali, of about the strength of 1° Twaddle's hydrometer, either in a boiling state, which renders an immersion of six hours sufficient, or at a temperature of 150° Fahr., which will necessitate the continuance of an immersion for about twelve hours. By this means the glutinous matters, which connect the fibres with the woody portions of the plant, are dissolved, and the colouring matters contained in the straw are discharged and prevented from staining the fibres. When the flax is required to be spun in long staple, the straw is next steeped for about two hours in dilute sulphuric acid, containing one part of acid to from two to five hundred parts of water, for the purpose of ridding it of the alkali which it has taken up; the straw is then removed from the acid-bath and well washed in water: this is one process. But the one which has raised the public curiosity, is that which purports to split the fibres into fine filaments like those of cotton or wool. This operation is effected as follows:—The straw is put into a bath containing a strong solution of bicarbonate of soda, and allowed to remain there for three or four hours. When well saturated with the bicarbonate, it is immersed in water, acidulated with sulphuric acid, in the proportion of one part of acid to two hundred parts of water; the sulphuric acid will then combine with the soda and effect the disengagement of carbonic acid gas in the fibrous tubes, which gas, by its expansive force, will split the fibres into fine filaments, having the appearance of fine cotton wool, and capable of similar treatment. This splitting process may be applied to the plant either in the state of straw, or after it has been retted and brought to the state of long fibre; and it is therefore capable of general application, as far as the inconvenience arising from bulk is concerned. What manufacturers will eventually say to working up fibres that have been steeped in sulphuric acid, may depend upon the means taken to extract this corroding substance from the flax; but at present we think there is a strong feeling against its use.

Mr. Claussen's patent process for treating flax is described as follows, in his specification of March, 1851:—

"1. My said invention, in so far as respects improvement in bleaching, has reference to the bleaching of all kinds of vegetable productions, and of fabrics or articles composed of such productions, and consists of the following improved processes. In the usual methods of bleaching fabrics, such as calico, the goods are first immersed in a bleaching liquor (commonly the solution of hypochlorite of lime, 'the chloride of lime' of commerce), and then are steeped in a bath of water, acidulated with sulphuric acid. By this plan, the chlorine is set free, either in its simple form, or in combination with oxygen (as chlorous or hypochlorous acids), or in chemical union with the hydrogen of the water (as hydrochloric acid), and thus either is wasted, by its escape, or is rendered injurious to the fabric, by remaining too long in contact with it.

"Now instead of this I adopt the following process, whereby the whole, or a great portion of the chlorine, or chloro-compound, is kept in a combined state, and recovered for further use. By the term 'chloro-compound,' I do not mean a salt containing 'chlorine,' but an acid having 'chlorine' for its base, such as chlorous or hypochlorous acid.

"In this process, then, of bleaching, I take the goods, after they have passed through the bleaching liquor (say a solution of the hypochlorite of lime), and then steep them in a strong solution of some salt, whose acid has a more powerful affinity for lime than hypochlorous acid; thus a strong solution of sulphate of magnesia may be employed, the sulphuric acid of which, having a strong affinity for lime, combines with the earthy base of the bleaching salt above-mentioned, and forms sulphate of lime, and the chloro-compound being thus liberated unites with the magnesia of the sulphate of magnesia, and forms a new salt (hypochlorite of magnesia), having bleaching properties similar to the lime-salt first employed.

"This newly formed compound may be, in the next instance, used as a primary bleaching agent, and may again be subjected to the process of double decomposition, as in the foregoing example. Thus, the goods having been exposed to the action of hypochlorite of magnesia in solution, may then be steeped in a liquid holding in solution some carbonate or other salt, for whose base the hypochlorous acid has a greater affinity than for the magnesia. In such a case, the carbonic acid having also a strong attraction for the magnesia, combines with it, to form a carbonate of that earth, and the liberated chloro-compound, instead of escaping, or remaining so long in contact with the goods as to injure them, combines with the base of the carbonate employed to produce decomposition, and forms a new salt, having bleaching properties. This salt may also be brought under the same laws of double decomposition, as exemplified before, and with similar results.

"Thus, if the carbonate employed in the foregoing instance had been carbonate of barytes, and a solution of sulphate of magnesia or of lime were brought into contact with the resulting chloro-compound salt of barytes, a precipitate of the base, as a ulphate of barytes, will take place, and the chloro-compounds will unite with the lime or magnesia, to form a bleaching salt.

"I would mention, however, that, in bleaching flax, or other like vegetable material for making linen, no compounds should be used which are likely, during their decomposition, to evolve any gaseous matters, such as carbonic acid or chlorine, as, by their development and expansion in the fibrous tubes, the flax, or any similar material, would be rendered not so fit for spinning with the ordinary flax spinning machinery; but in bleaching flax, or any similar material which is to be combined with other materials for spinning and felting, according to my invention, compounds evolving gas may be safely used, as I shall hereafter more fully specify and explain.

"For the purpose of bleaching by the method of double decomposition, I do not confine myself to the compounds already mentioned as examples, nor to any particular salts or class of salts; but I claim a right to use salts, which, when placed under the like circumstances, as before exemplified in the case of goods treated by the hypochlorite of lime and the sulphate of magnesia, will be subject to the same chemical law of decomposition, and will produce the same result. However, I may particularise as among the salts suitable for decomposing the chloro-compounds, or assisting themselves in the process of bleaching, the carbonates (such as the carbonate or bicarbonate of soda), sulphates (as sulphate of magnesia, &c.), nitrates (as nitrate of soda, &c.), acetates (as acetates of potash and of lead, &c.), prussiates (as prussiates of potash, &c.), chromates (as chromate and bichromate of potash, &c.), tartrates (as tartrate and bitartrate of potash, &c.); but I repeat that I do not confine myself to these, which are merely given as examples.

"Another mode of bleaching which I sometimes employ, and which is especially applicable to goods composed of both animal and vegetable fibre, is as follows:—I take the goods, after they have been steeped in any of the ordinary bleaching liquors, such as the solution of hypochlorite of lime (chloride of lime), and while they are still wet, expose them to the fumes of sulphur, slowly burning in a suitable chamber or stove. In this case, I have two powerful bleaching agents at work, viz., the hypochlorite compound, and the sulphurous acid produced by the combustion of the sulphur. A portion of the sulphurous acid combines with the base of the chloro-compound salt, to form a sulphate of lime or magnesia, as the case may be, and a small portion of sulphuric acid may also in this case be formed, which, with the earth or base, would form a sulphate. In this way the chlorine, or chloro-compound, remaining in the wetted goods is liberated, and allowed to act freely upon the articles to be bleached. In this last method of bleaching I have ascertained that there may be occasionally substituted for the ordinary and known bleaching liquids certain chromates, manganates, and hypermanganates, &c.

"Secondly. My improvements in the preparation of materials for spinning and felting have special relation to flax and hemp, and other plants, to which the same may be applicable: and the processes I use to prepare the same, though possessed of some features common to the whole, vary according to the purposes to which the fibre obtained from the said materials is to be applied, that is to say, according as the fibre is required to be long or short, fine or coarse, and the machinery in which it is to be spun is adapted to the spinning of one or other sort of fibre. By the term 'fibre,' as used throughout the specification, I mean that portion of each plant which is capable of being spun or felted; and my invention applies to the 'fibre' surrounding the stems of dicotyledonous plants, and to that existing in the stems and leaves of monocotyledonous plants.

"In the following exemplifications of my improved modes of preparation, I shall throughout suppose flax or hemp to be the material operated upon.

"If I have to deal with the plant from the time of its being first cut down or pulled for use, I take it in the state of straw (after the seed had been stripped from it), and subject it to the following, which I call my 'primary process':—

"I first steep the straw in a solution of a caustic alkali of about 1° of Twaddle's hydrometer, and for such a length of time as may be most convenient. If despatch is required, I use the solution in a boiling state; in which case an immersion of about six hours is sufficient. If more time can be conveniently allowed, I employ a solution of a temperature of about 150° Fahr., and prolong the immersion for about twelve hours; and so in proportion to the degree of temperature. The solution may be even used at a lower temperature, with a corresponding prolongation of time, but in no case need the immersion exceed a couple of days at the utmost.

"The object of the preceding treatment is two-fold:—first to decompose, dissolve, or remove (more or less, as required), the glutinous, gummy, or other matters, which connect the fibre with the woody portions of the plants; and second, to discharge or decompose any oleaginous, colouring, or extraneous matter contained in the straw, without allowing the matters so discharged to stain the fibre; and these results are obtained by the action of the alkaline solution. In the preceding mode of preparing vegetable materials, I generally use a solution of caustic soda; but other alkaline liquors will answer the purpose,—such as a solution of caustic potash, or of lime dissolved in or diffused in water, or, indeed, any substance having the like power of removing, discharging, or decomposing the colouring, glutinous, gummy, or other foreign matters contained in the straw, and which would interfere with the whiteness of the fibre, or with its ready separation and manufacture.

"If the fibre is required to be long, like that now commonly spun in flax machinery, I subject the straw to a second process, for the purpose of getting rid of any of the alkali still adhering to the straw or fibre, and for the purpose of completing (if necessary) the removal of any glutinous, gummy colouring, or extraneous matters.

"To this end I will take the straw from the alkaline solution, and steep it for about two hours in water acidulated by sulphuric acid, in the proportion of about one part of the acid to from two to five hundred parts of water. Some other dilute acids will also answer this purpose, such as dilute muriatic acid, &c.; but sulphuric acid is to be preferred. Or, I transfer the straw, while yet wet with the alkaline solution, to a suitable chamber or stove, where I subject it to the action of sulphurous acid, or the fumes produced by the slow combustion of sulphur. In both cases, the acid combines with any free alkali remaining on the straw or fibre, to form a sulphite or sulphate, according to the acid employed; while an excess of either sulphuric or of sulphurous acid will complete the decomposition, discharge, or removal of the glutinous, colouring, and other matters.

"I next remove the straw from the acid bath, or sulphur chamber or stove, and wash or otherwise treat it with water, till all soluble matters are removed.

"If the fibre is required to be discolorised, the straw may now be exposed to one of the bleaching processes which I have already described, or to any of the other known bleaching processes. It may then be dried, and made ready for breaking and crushing, by the means ordinarily followed in the manufacture of long flax.

"I would mention here that, in some cases it will be found advantageous to pass the straw between rollers, or to break it roughly or partially, before subjecting it to the process above described, for the purpose of facilitating the action of the chemical agents upon it.

"By the aforesaid method, I am enabled to remove from the straw certain matters, which water alone can discharge. The fibre thus prepared is also freer to heckle, and the straw more easy to scutch, than fibre and straw treated in the ordinary way. Much time and much material are also saved; while the noxious exhalations attendant upon the water-rotting system are wholly prevented.

"If the fibre is required to be short, so that it may be felted or carded, and adapted for spinning on cotton, silk, wool, worsted or tow-spinning machinery, either alone or in combination with cotton, hair, fur, silk, or shoddy, I take the fibre, after treating it by the processes just described, and divide it in proper lengths, by some suitable instrument or machine. I then transfer the straw or fibre to a bath containing a strong solution of bicarbonate, or even carbonate of soda, or any other similar compound; but the first two of these are to be preferred, as most abounding in carbonic acid. In this bath I allow it to remain for about three or four hours, during which time the fibre becomes well saturated with the salt. I then immerse the materials, impregnated with the solution of the carbonates before named, for about a couple of hours in water acidulated by sulphuric acid, of about the strength of one part of acid to two hundred parts of water. Or, instead thereof, I expose the saturated materials, while wet, to the action of burning sulphur in a suitable chamber or stove.

"In this operation it appears that a certain portion of gas being developed in the fibrous tubes, splits and divides them by its expansive power into filaments, having the character and appearance of fine cotton wool; in which state they may be dyed and manufactured like cotton or wool.

"The same means of effecting the splitting of the fibre may of course be employed in the preparation of long fibre, and I do not limit myself to its use for the preparation of short fibres alone, but when the fibre is of its original length, the solution employed takes a longer time to penetrate the interior.

"The decomposition of the bicarbonate of soda or other suitable compound, with which the fibre is saturated, may be also effected by means of electric agency, when a like evolution of gas and splitting up of the fibre will take place.

"After the fibre has been subjected to the splitting process, it must be carefully washed to remove all soluble matters, and then dried.

"The splitting process may be applied to the plant, either in the straw (the wood of which is to be afterwards removed by proper means and machinery), or in the state of long fibre, whether prepared by my before-described process, or by any of the usual and known processes.

"Thirdly, my invention, in so as it relates to improvements in yarns and felts, consists in composing the same of the following new combination of materials. I manufacture a yarn which I call 'flax cotton yarn,' composed partly of flax fibre prepared and cut into short lengths, as aforesaid and partly of cotton, varying the proportions at pleasure. This yarn is much stronger than yarn composed of cotton alone, and also much whiter and more glossy, while it is equally capable of being spun in the ordinary cotton spinning machinery.

"I also manufacture yarns composed in like manner, partly of hemp fibre or of jute, or of *phormium tenax*, or of other like vegetable fibre (china grass excepted), prepared and cut into short lengths, as aforesaid, and partly of cotton, which yarns each possess the same properties (more or less) as the flax-cotton yarn.

"I manufacture also a yarn, which I call 'flax-wool yarn,' composed partly of flax prepared and cut into short lengths as aforesaid, or of any other like vegetable fibre (cotton and china grass excepted) and partly of wool, or of that description of it called 'tschudy,' or partly of fur or hair, or partly of any two or more of the said materials; which yarn is stronger than any yarn composed of wool alone. Some wools also, which are too short to be spun by themselves, may, by being mixed with flax fibre, cut into short lengths, form a material very suitable for spinning.

"I manufacture also a yarn, composed partly of flax or other like vegetable fibre (china grass excepted), prepared and cut into short lengths, as aforesaid, and partly of waste silk, that is, silk of the short lengths in which it exists before reeling, or silk rags cut into short lengths and carded.

"Lastly, flax-felts, of a fineness and softness equal to the best felts composed wholly of wool, and superior to them in point of durability, are also produced by a mixture of flax fibre, prepared and cut into short lengths, as aforesaid, with wool, fur, hair or any other feltable material.

"And I declare that what I claim, as secured to me by the said letters patent, is as follows:—

"First,—I claim the method of bleaching by double decomposition, before described, whereby the various bleaching agents and compounds used may be recovered and economised.

"Second,—I claim the method of bleaching by the combined action of chlorides, or carbonates, or chromates, or any other bleaching agent, with fumes of sulphur, as before described.

"Third,—I claim the preparing of flax and hemp, and of all vegetable fibre capable of being spun or felted, from whatever description of plants obtainable, by steeping the plant from which the fibre is derived, while in the state of straw, stem, leaf, or fibre, first in a solution of caustic soda, or other solution of like properties, and then in a bath of dilute sulphuric or other acid, as before exemplified and described.

"Fourth,—I claim the preparing of the said vegetable fibre for spinning in cotton and silk machinery, and for being confined with cotton, wool, raw silk, or other materials of short staple, by firstly steeping the same in a solution of caustic soda, or other solution of like properties. Secondly, steeping them in a bath of dilute sulphuric or other suitable acid, or exposing them to the fumes of sulphur. Thirdly, saturating them with a solution of bicarbonate of soda or any other like agent, and then decomposing such salt, however such decomposition may be effected; and, fourthly, cutting them up into short lengths, all as before exemplified and described.

"Fifth,—I claim the employment generally in the preparation of flax, hemp, and other sorts of vegetable fibre, of the mode of splitting by gaseous expansion, as before described, whether the fibre is long or short, and whatever may be the purpose to which the same is to be applied.

"Sixth,—I claim the manufacture of yarns and felts from a combination of flax, or like vegetable fibre (china grass excepted), prepared and mixed, as aforesaid, with cotton wool, 'tschudy,' silk waste, fur, and hair, all or any of them as before exemplified and described."

Another process for treating flax is shortly to be introduced, which is said to surpass that of M. Claussen in its results. This is the patented invention of Mr. Bower, of Hunslet, but as his specification is not yet enrolled, we withhold, for obvious reasons, the details of his plan, and forbear to express any opinion of its practicability. The treatment of flax, in its early stages, is a matter of vast importance to this country; and perhaps there is no one problem throughout our manufactures whose solution would better repay the successful experimenter, than how the facilities for working cotton and wool are to be communicated to flax.—*Newton's Journal*, October, 1851.

Mr. D. F. Bower obtained in March, 1851, a patent for retting and preparing flax, in which he submits the flax, after steeping it for six days in cold or hot water, to the pressure of rollers once and again, with steeping, in order to expel the glutinous matter, and then dries it. Line is treated with dilute water of ammonia, or alkaline saline solution. He also avails himself of the air-pump, along with the above solvents, for the extraction of the gluten by means of hot water.

With the object of giving the flax grower the means of rendering his produce fit for the market, Mr. M‘Pherson, of Edinburgh, has constructed a portable breaking and scutching machine, suitable for a farmstead. It consists of two rectangular wooden cases, of unequal size, connected together side by side, the smaller containing the breaking apparatus, and the larger the parts for scutching the flax. The small case is provided with a horizontal table, having a fluted surface, whereon the flax is laid; and over the table a fluted roller is caused to travel, for the purpose of cracking the boon, or woody portion of the flax plant. The axes or pivots of the roller move in horizontal guides, which can be lifted by depressing a treadle, for the purpose of raising the roller, and the traverse of the roller is effected by its connection, through a rod, with a crank on the end of a short horizontal shaft, which is caused to revolve by horse or other power. The shaft also carries a spur wheel, gearing into a pinion upon another horizontal shaft, that extends through the large case. Upon this second shaft (within the large case) are fixed two discs or bosses, to which four pairs of long radial arms are bolted; and to the outer ends of each pair of arms is fastened a wooden beater, of a *L* shape, in the transverse section. At the top of the large case two channels are made to receive the clamps, in which the stricks of flax to be scutched are held to receive the blows of the beaters. The flax is first laid upon the fluted table, and submitted to the action of the traversing roller until the boon is broken up and sufficiently loosened from the fibre; it is then removed, and secured in given quantities between a pair of clamps, in such a manner that one-half the length of the plant is pendent therefrom. Clamps or holders thus filled are successively passed into one of the channels in the large case, and as they are pushed forwards towards the other end of the machine, the stricks of flax are brought under the action of the rotating beater, whereby the pendent portion of the flax is cleared of its boon. When this is effected, the holders are removed from the channels and opened, to turn the end of the flax; the clamps are then again tightened and introduced into the other channel, to bring the other end, in like manner, under the action of the beaters. When the apparatus is in full operation, both channels will be full of holders; and the introduction of a fresh holder at one end is the means whereby a holder, containing a strick of scutched flax, is discharged at the opposite end. This machine, according to the statement of the inventor, is calculated, by the application of from three to four horse power, to clean half an acre of flax per diem.

Mr. Plummer, of Newcastle-upon-Tyne, has exhibited machinery, and of a new construction, for breaking and scutching flax, and for heckling what is technically known as "cut line." The breaker consists of a cast-iron framing, carrying five fluted rollers of similar diameters, and connected together by geering wheels, so that the driving of the axle of one by a band and pulley will cause the other to rotate at the same speed. This machine is provided with two platforms, the one for conducting the flax to the rollers, and the other for guiding it out of the machine. The rollers are so arranged as to bite the flax three times during its passage through the machine; and the top rollers are weighted, for insuring a proper amount of pressure being put upon the flax.

The scutching machine consists of a rotary vertical disc inclosed in a casing, and carried by an axle working in suitable bearing, supported by the frame of the machine. On each side of the disc radial beaters, or wooden knives, having a bevelled edge on their inner face, are fixed; but on one side of the disc the beaters are alternated by radial brushes, the object being to submit the flax, first to the action of the beaters only, and then to effect the more thorough separation of the boon from the fibre by the combined action of brushes and a second set of beaters. An opening is formed in the front of the case through which the flax is introduced by hand to the action of the beaters. When one end is cleaned, the operator turns ends, and again submits the flax to the scutching operation. By the use of a solid disc in place of radial arms (as hitherto used) for carrying the beaters, it would seem that greater speed than hitherto applied may be used without the risk of breaking the staple, as the objection presented by the arms, of causing the flax to lash round them, and thereby get broken when working at great speed, is necessarily avoided.

The next stage of treating flax is to subject it to the action of the heckling machine, whereby the flax is combed out, and its fibres are subdivided to the extent required; the short entangled fibres being at the same time removed from the more valuable staple. The extent to which the separation is carried is to produce a yield of only from 50 to 80 lbs. of "dressed line," as the more valuable staple is termed, out of 112 lbs. of scutched flax, the remainder constituting the raw material known as tow, which in general goes to form an inferior description of yarn. If the flax is intended to be spun to a fine quality of yarn, or a "high number," it is cut into two, three, or more lengths, before being submitted to the heckling machine; the coarser parts of the staple, that is, the extremities, being separated from the others, to form a medium

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quantity of yarn, while the middle portions are selected for conversion into fine yarn. The action of the heckling machine, as far as the operation itself is concerned, is the same whether the long or short staple be heckled; but, to effect the operation economically, that is, without making an undue amount of tow, different constructions of machines are preferred for dressing the long and the cut line. For heckling the latter kind of staple, Mr. Plummer exhibited a machine embracing some novel points deserving of notice. It is of that class of machines which have two heckle cylinders revolving in opposite directions, and dressing both sides of the strick of flax simultaneously, but which have hitherto met with very partial success, as the cost with which they work scarcely compensates for the waste of material they occasion, from the fact of two sets of heckles entering the strick simultaneously, and tearing through it without the power of yielding to the entangled or interlocked fibres. Now, in order to remedy this evil in part, one of the cylinders is mounted on sliding bearings; so that each strick of flax, on being first presented to the heckle-pins, will be partially combed by the cylinder, which is mounted in stationary bearings, before the traversing cylinder approaches to act upon the strick. These cylinders are furnished with three grades of heckle-pins, and the rows on the first, or coarsest set, are alternated by rows of brushes. The motion for traversing the holders, containing the stricks of flax through the machine, is somewhat novel and ingenious. Mounted near one end of the holder trough (which receives its up-and-down motion for bringing the length of stricks gradually under the operation of the heckle cylinders by the ordinary arrangements of mechanism) is a short axle, which carries three pinions, two of which take into vertical racks, attached to the end framing; and the central pinion geers into a rack formed on a horizontal reciprocating bar, carried by the trough, and provided with loose pendent fingers. As the trough ascends to take in a fresh holder, the pinions, working on the fixed vertical racks, are rotated, and thus the central pinion is made to draw forward its rack with the sliding rod; by which means the pendent fingers are brought in contact with the holders, and caused to propel them forward. On the descent of the trough, the reverse action takes place; and the reciprocating bar being slidden back, the fingers, which are hinged so as to pass back over the holders, are brought to a proper position for propelling them forward on the next ascent of the trough; this reciprocating bar is common to many heckling machines, but the mode of actuating it appears to us to be both new and simple. On the ascent of the trough to receive another holder, and discharge at the same time a holder of heckled flax, the traversing cylinder is caused to retire by a simple mechanical contrivance, and thus allow of the strick of flax just received into the machine, as well as those, which, in consequence, have been shifted forward to a finer set of heckle pins, to be brought, first under the action of the heckle cylinder, which works in stationary bearings, and then under the action of the pins of the traversing cylinder, as before explained; the ascent of the trough being made the means of driving back the cylinder, and its descent allowing of its moving forward to operate upon the flax. The heckle cylinders are cleaned as usual by rotating brushes; and an endless band of lattice-work is provided for gathering the tow into a proper receptacle. Whether or no this machine is destined to take a permanent place in our flax manufactories, a mere inspection of it in its quiescent state is not sufficient to enable us to judge: as regards compactness, it has greatly the advantage of the double cylinder machines of Messrs. Lawson & Sons, of Leeds, whose contribution we shall next notice; but we can give no opinion of their relative merits in other respects.

This firm has made by far the largest display of flax machinery; and, indeed, the credit is mainly due to them that the Great Exhibition has represented this important branch of our manufactures. Their contribution may be briefly stated to have included a complete set of machinery for heckling, spreading, drawing, and roving long and cut flax; also for carding, drawing, and roving tow; for spinning coarse and fine flax yarn; and likewise for manufacturing thread. For treating short flax, a pair of cylinder heckling machines were exhibited. The cylinders, instead of being set abreast of each other, and acting simultaneously on the flax, are mounted in a line, and revolve in opposite directions, so that the flax is dressed, first on one side by one cylinder, and then on the opposite side by the other cylinder. The objection to this arrangement is, as before indicated, the want of compactness; as machines working on this principle are required to be double the length of those which turn the strick and heckle both sides on the same heckle-pins, or heckle it simultaneously on both sides. To remedy this objection, however, Messrs. Lawson apply two troughs to the machine, and are thus enabled to submit two rows of stricks to the action of the same rotating heckle cylinder. The mode of traversing the flax holders through the machine is analogous to that described in reference to Mr. Plummer's machine, and therefore need not to be repeated. The cylinders are furnished with two grades of heckle-pins; and between each row, rising and falling plates (which take their motion from excentrics) are fitted for the purpose of determining the depth that the heckle-pins shall enter the stricks. Between the rows of the finer grade of heckles, small flat brushes being set in one edge of the rising and falling plates form a sort of bed for the flax to lie on while under the action of the heckles. The stricks, in passing over one cylinder, are heckled on one side; they are then brought under the action of the second cylinder, which, revolving in an opposite direction, will finish the other side of the strick. The machine exhibited by this firm for operating upon long fibres is provided with two endless bands of heckles, set side by side, and arranged so as to present an inclined surface to the flax. These bands are set at opposite inclines, and revolve in different directions, for the purpose of operating upon different sides of the stricks of flax. These are the only arrangements of heckling and machinery which the Exhibition contained. It must, therefore, be considered as very deficient in this respect, as the rival inventions of Messrs. Marsden, of Manchester, and Messrs. Combe, of Belfast, for turning the stricks of flax, and causing them to be operated upon on both sides by the same cylinder (which have recently been the cause of so much litigation) are unrepresented. So also is a still more recent improvement of Messrs. Combe, for heckling both sides of the strick without turning, by the use of but one cylinder. In this machine (which we have had recently an opportunity of seeing in action at Belfast) the means of operating on both sides of the strick is obtained by merely reversing the direction of rotation of the cylinder, while the trough is ascending to take in a fresh holder. Another arrangement of a promising character, for passing once through the machine, has recently been devised by Messrs. Harding, Cocker, & Co., of Lille; but as this machine was not included in their contribution to the Exhibition, we conclude that it is not yet brought into the market. The flax, after leaving the heckling machine, is slightly combed by hand, and sorted into parcels, according to the quality of the staple; it is then packed away in a cool, dry, dark room, and by lying there for a few months its quality is said to improve. When the flax is taken from the "dressed line store," it is subjected to the action of the following machines, for the purpose of converting it into yarn, viz.; 1. The first drawing frame, or spreader, the use of which is to convert the flax, as delivered from the heckling machine, into a continuous sliver or band of filaments; 2. The second drawing frame, by which the sliver is attenuated; 3. The third drawing frame, whereby several slivers from the second drawing frame are united together and redrawn, to obtain a finer sliver, with greater regularity of fibre; 4. The roving frame, which further elongates the sliver, and converts it into a spongy cord or roving; 5. The throstle frame, which extends the spongy or loose roving, and spins it into yarn. The flax drawing frame is very different in construction to that formerly described as employed for drawing cotton, although the action is precisely analogous. Its constructions and mode of operation may be thus briefly described: at the back of the machine is an endless travelling feed-cloth, on which the stricks of flax are laid, so as to overlap each other, and which carries the flax to what are termed the back holding rollers. In front of these rollers, and arranged parallel thereto, is a series of "gills" or straight bars furnished with heckle-pins, whose office is to receive the flax as it is delivered from between the holding-rollers, and carry it forward to the drawing-rollers. These gills are supported and traversed by their extremities, taken into the threads of two screw shafts, set at right angles to the holding rollers, which shafts, as they rotate, carry the gills forward. When they have arrived at the end of the shaft they severally fall, and are received by a pair of screw shafts below, having a quicker thread, which carry them back to the holding rollers, and a sweep, on the end of these shafts, lifts the gills up again into geer with the upper screw shafts. Thus an endless chain, as it were, of gills is provided, which, having a somewhat greater speed than the holding rollers, combs the flax straight and delivers it with perfectly parallel fibres to the drawing rollers. By these the sliver is drawn to the requisite fineness, and then, passing between a pair of calendering rollers, it is delivered to a can. The cans of sliver, thus produced, are now set up behind the second drawing frame, to undergo the second operation. This frame, and also the third, are similar in construction to the first; the only difference being, that they are fed from cans instead of by a cloth; and as the progress of drawing out the sliver advances, the size of the working parts are required to be less, and the fineness of the gills to be increased. The operation of drawing is the same in all cases; but in the second and third frames, the sliver is doubled, to give it an evenness, or structural equality, as it is elongated.

Messrs. Lawson have exhibited screw gill spreaders (as the first drawing frame is termed) for both long and cut flax; also gill frames for completing the drawing of the long and short fibre, but further than being well made machines, they present no points for comment.

Messrs. Higgins & Sons have also exhibited a screw gill spreader and a second drawing frame for long lines. In the former of these machines the front top rollers are weighted by an arrangement of compound levers, which is said to have the advantage of convenience over the ordinary plan; and in the latter, the roller and gills are driven at the middle instead of the side of the machine; thus relieving the rollers of a great portion of the strain to which they are ordinarily exposed, and permitting of the use of smaller rollers, which, for some descriptions of work, is considered of importance.

The sliver, as it is delivered into cans from the third drawing frame, is taken to the roving frame to be still further reduced and wrought into a loose thread; but as this operation is precisely similar, whether for long line, cut line, or tow, it may be well to explain briefly the means of bringing tow to a proper state for undergoing the first spinning process before speaking of the roving frame. The tow, which we have said is the short and irregular fibres combed out of the strick of flax by the heckling machine, is subjected to the action of a carding engine, somewhat similar in construction to that used for carding cotton. It consists principally of a large central cylinder, covered with wires, cards, and surrounded by card rollers termed "workers" and "strippers," revolving in contact therewith. The tow is carried into the machine by an endless travelling cloth, which delivers it to a pair of feed rollers, situate below the main cylinder, whereby it is transferred to the large cylinder. By this it is brought under the action of the workers, when combed or carded; and it is then stripped or "doffed" from the cylinder by card rollers, which in their return are relieved of the staple by doffer combs; these take it off in the form of a sliver, and it is eventually delivered from the machine by delivering rollers into cans. In order to prevent the liability of the sliver breaking by being pressed down into the cans, and also to avoid the necessity of using a separate machine for performing the first drawing operation, it has lately been the practice to apply one or more gill-drawing heads to the carding engine, according to the number of strippers employed and slivers produced, and carry on the carding and the first drawing processes simultaneously. This arrangement, patented by Messrs. Fairbairn & Co., was applied to Messrs. Lawson & Son's carding engine. It is provided with three strippers, which are capable (by being set at different distances from the main cylinder) of taking off different lengths of staple from the card surface, and thereby sorting out or dividing the qualities of the tow. In this machine, however, there is but one gill-head; all the slivers, therefore, are united in the first drawing process, and form together a continuous sliver; the completion of the operation of drawing tow is precisely similar to that already described with reference to long and cut line.

To obtain a flax roving, it is usual, after drawing the sliver to the required amount, to put in its slight twist. Messrs. Higgins exhibited a roving frame with six heads and sixty spindles, for producing roving of this kind. This roving frame is, in fact, to describe it shortly, a drawing frame, with the addition of spindles; the gills and rollers being driven according to their improved plan, before noticed.

The roving frame for cut flax exhibited by Messrs. Lawson, is intended to produce a roving without twist, which, for obtaining fine qualities of yarn, is very desirable; the gummy matter in the flax is here taken advantage of to give the roving the necessary cohesive property. A correct notion of the construction of this roving frame may be best conveyed by tracing the progress of the sliver through the machine. The sliver passes from the can over a pulley through fixed guides over travelling gills, between a pair of drawing rollers, then into a trough containing hot water (for the purpose of dissolving the gummy matter in the flax), then over a heated cylinder which dries the staple, and finally it is wound on to a bobbin, which rests upon and turns in contact with a horizontal fluted roller. Rovings thus produced are capable, it is said, of being drawn to almost any degree of fineness, with little reference to the material; because one fibre can be glued to another; at any portion of its length a roving can be made. Messrs. Lawson also contributed machinery for wet and dry spinning, viz., a dry tow spinning frame, with 100 spindles; a fine spinning frame for spinning the roving through cold water; a double water frame, with 136 spindles; and a double twisting frame with 96 spindles. The only noticeable novelty in these machines (the construction of which will be understood from the description already given of cotton spinning machinery) is a new tape motion for driving the spindles. A spinning frame, by Messrs. Higgins, containing 144 spindles was also exhibited; but further than being a specimen of good design and workmanship, it calls for no special remark.

Retting of Flax.—Mr. Watt's system of flax retting may be briefly described as follows:—The flax straw is delivered at the works by the grower, in a dry state, with the seed on. The seed is separated by metal rollers, and afterwards cleaned by fanners. The straw is then placed in close chambers, with the exception of two doors, which serve the purpose of putting in and discharging the straw. The top, which is of cast iron, serves the double purpose of a top and condenser. The straw is then laid on a perforated false bottom of iron, and the doors being closed, and made tight by means of screws, steam is driven in by a pipe round the chambers, and between the bottoms; and, penetrating the mass, at first removes certain volatile oils contained in the plant, and afterwards is condensed on the bottom of the iron tank, and descends as a continuous shower of condensed water, saturating the straw. This water is a decoction of extractive matter, to which attach the fibrous and more porous portions. This liquor is run off from time to time, the more concentrated portions being used for feeding.

The process is shortened by using a pump, or such an arrangement as rapidly washes the mass, with the water allowed to accumulate. In about eight or twelve hours, varying with the nature of the straw, it is removed from the chambers, and, having been robbed of its extractive matter, it is then passed through the rollers for the purpose of removing the epidermis, or skin of the plant, and of discharging the greater part of the water contained in the saturated straw, and while in the wet and swollen state, splitting it up longitudinally. The straw then (being free of all products of decomposition) is easily dried, and in a few hours ready for scutching.

In the experimental trial, personally superintended, throughout all its details, by the Committee, a quantity of flax straw, of ordinary quality, was taken from the bulk of the stock at the works, weighing 13¾ cwts. with the seed on. After the removal of the seed, which, on being cleaned thoroughly from the chaff, measured 3¾ Imperial bush., the straw was reduced in weight to 10 cwt. 1 qr. 21 lbs. It was then placed in the vat, where it was subjected to the steaming process for about eleven hours. After steeping, wet-rolling, and drying, it weighed 7 cwt. 0 qrs. 11 lbs.; and, on being scutched, the yield was 187 lbs. of flax; and of scutching tow, 12 lbs. 6½ ozs. fine, and 35 lbs. 3 ozs. coarse. The yield of fibre, in the state of good flax, was, therefore, at the rate of 13½ lbs. from the cwt. of straw with seed on; 18 lbs. from the cwt. of straw without seed; 26¼ lbs. from the cwt. of steeped and dried straw.

The time occupied in actual labour, in the processes, from the seeding of the flax to the commencement of the scutching, was 13½ hours, to which, if 11 hours be added for the time the flax was in the vat, 24 hours would be the time required up to this point. The scutching, by four stands, occupied six hours sixteen minutes. But, in this statement, the time required for drying is not included, as, owing to some derangement in the apparatus, no certain estimate could be made of the actual time required in that process. It would appear, however, that about thirty-six hours would include the time necessary, in a well-organized establishment, to convert flax straw into fibre for the spinner.

The cost of all these operations, in this experiment, leaving out the drying, for the reasons noted, appeared to be under 10*l.* per ton of clean fibre, for labour, exclusive of general expenses.

A portion of the fibre was sent to two spinning-mills to be hackled, and to have a value put upon it. The valuation of the samples varied from 56*l.* to 70*l.* per ton, according to the quality of the stricks of fibre sent, and the yield on the hackle was considered quite satisfactory.

On the results of this experiment, which was necessarily of a limited nature, the Committee think it best to offer no general remarks. They are sufficiently favourable to speak for themselves. It remains to be ascertained whether the qualities of flax fibre prepared by this method are such as to suit the spinner and manufacturer. They have been informed, by a spinner who has been trying some flax prepared by Mr. Watt's system, that the yarn made from it appears equal in all respects to what is ordinarily spun from good Irish flax, of the finer sorts. They believe that, before long, information will be given by several individuals who are about to carry out more extended trials on the spinning and manufacturing departments.

The Committee conceive that the most prominent and novel feature of this plan consists in the substitution of maceration, or softening, for fermentation. In the steeping of flax, both by cold and hot water, the fibre is freed from the substance termed gum, by the decomposition of the latter, while in Watt's system the maceration of the stems loosens the cuticle and gum, which are further separated mechanically in the crushing operation, and, after the drying of the straw, readily part with the wood, under the action of the scutch-mill.

Before concluding this statement, the Committee wish to call attention to a very curious feature in Mr. Watt's invention. The water from the vats, in place of being offensive and noxious, as is the case with ordinary steep water, contains a certain amount of nutritive matter. This arises from its being an infusion of the flax stems, in place of holding in suspension or solution the products of the decomposition of the gum, and other substances contained in the stems. The inventor is now employing this water, along with the chaff of the seed-bolls, for feeding pigs. It is of much interest, therefore, to note in how far this may be found practically to answer, as, between the seed, the chaff, and the water, by far the greatest portion of what the flax plant abstracts from the soil, would thus be returned in the shape of manure. However this may turn out, the avoidance of all nuisance in smell, and of the poisonous liquid which causes some damage among fish when let off into rivers, is a matter of some consequence.

Appended to this report is a note of the time occupied in the different processes during the experiment, and of the number of persons employed in each.

It is to be hoped that so promising a plan may, on more extended experience, be found fully to warrant the high anticipations formed from what is already known concerning it. (Signed on behalf of the Committee),

Richard Niven, Chairman.

Belfast, 3d Nov., 1852

APPENDIX.

Note of the time occupied, and of the number of persons employed in each of the processes witnessed by the Committee, on the experimental trial of Mr. Watt's system of preparing flax fibre:—

	No. of persons employed.		Time occupied.	
	Men.	Women and Boys.	Hours.	Minutes.
Seeding, - - - - - -	4	8	1	15
Placing in Vat, - - - - -	3	4	0	15
Cleaning Seed, - - - - -	1	0	3	0
Taking out of Vat, - - - -	2	3	0	30
Wet-rolling and putting in Drying Room, - - - - - -	1	16	2	20
Rolling for Scutching, - - - -	0	11	1	8
Stricking for do., - - - -	0	7	4	47
Total,	11	49	13	15
Scutching, - - - - -	4	0	6	16

Cultivation of Flax in Flanders.—There is a very fine long variety of flax which is cultivated in the neighbourhood of Courtray, in Flanders; it requires a very good soil to grow in, and the stem is so long and slender, that, if it were not supported, the least wind would break it and lay it flat, in which case, the quality of the flax would be much impaired and the quantity reduced. To prevent this, short stakes are driven into the ground in a straight line, at 8 or 10 feet from each other, and long slender rods are tied to them with oziers, about 1 foot or 18 inches from the ground, forming a slight railing to support the flax; a number of these are placed in the same manner at a short distance from each other in parallel lines all over the field, and the flax is thus prevented from being beat down. A better method, which is not commonly adopted, is to have stakes in regular rows, and thin ropes tied to them, instead of rods; by having these lengthwise and others across them at right angles, a kind of large net is spread over the whole field, and none of the flax can possibly be laid flat. By using cheap rope, or strong tar-twine from old cables, the expense is not very great, and much less room is taken up than by the rods. When the flax is pulled, the stakes are taken up, and removed to a dry place till they are wanted again.

The most common variety of flax is of a moderate length, with a stronger stem; if it is not sown very thick it will throw out branches at top and produce much seed; it is therefore a matter of calculation whether it will be most profitable to have finer flax with less seed, or an inferior quality with an abundance of seed.

There is a small variety which does not rise above a foot, grows fast, and ripens its seed sooner. When linseed is the principal object, this variety is preferred; but the flax is shorter, and also coarser.

Another variety of flax has a perennial root, and shoots out stems to a considerable height. It came originally from Siberia, and was much recommended at one time, but its cultivation did not spread. If it were sown in wide rows, and kept free from weeds by hoeing, it might, perhaps, be profitably cultivated for the seed; and if the flax is inferior in quality, it might still be of some value for coarse manufactures; it requires, however, to be renewed every three or four years and sown in fresh ground.

The soil best adapted to the growth of flax is a deep rich loam, in which there is much humus, or vegetable mould. It should be mellow and loose to a considerable depth, with a sound bottom, neither too dry nor too moist; either extreme infallibly destroys the flax; it is therefore not suited either to hot gravelly soils or cold wet clays, but any other soil may be so tilled and prepared as to produce good flax. It thrives well in the rich alluvial land of Zealand and the Polders, but it is also raised with great success in the light sands of Flanders, but much more careful tillage and manuring are required. The land on which flax is sown must be very free from weeds, the weeding of this crop being a very important part of the expense of cultivation. These circumstances suggest the best mode of preparing the land. A long fallow, such as is sometimes given to the land in Essex, including two winters and a summer, may be a good preparation on the heavier loams, which should be trenched, ploughed, and worked deep; the manure should be dung fully rotten, or a compost of earth and dung; it should be put on the land in autumn, and well incorporated before the seed is sown. If the land is sufficiently clean, a crop of potatoes well manured may be substituted with advantage for the fallow; but at least double the usual quantity of dung should be given to this crop, that enough may remain in the ground for the flax. Lime may be used if the soil contains a great portion of clay; but in the lighter loams there is some doubt of its advantage for flax. At all events it should not be used immediately before the flax is sown, but for some previous crop. Peat-ashes are excellent; they improve the soil and keep off insects, which are apt to injure the roots of the flax. For want of peat-ashes, those made by the burning of weeds and earth in a smothered fire are a good substitute. But the most effective manure is the sweepings of the streets in towns, mixed with the emptying of privies, and the cleaning out of the butchers' stalls and shambles. On light soils much manure is required: and where night-soil cannot be obtained in sufficient quantities, rape-cakes, from which the oil has been expressed, dissolved in cow's urine, form the best manure. In many parts of Flanders, 500 rape-cakes are used for every acre of flax, besides the usual quantity of Dutch ashes and of liquid manure, which is the drainings of dunghills, and the urine of cattle collected in a cistern, and allowed to become putrid.

In southern climates flax is sown before winter, because too great heat would destroy it. It is then pulled before the heat of summer. In northern climates the frost, and especially the alternations of frost and thaw, in the early part of spring, would cause the flax to perish; it is, consequently, sown as early in spring as may be, so as to avoid the effect of hard frost. This is in March or April, in Great Britain and Ireland, and in Holland and Flanders. In no country is the ground better prepared for the growth of flax than in Flanders; and it may, therefore, be interesting to follow the whole process of Flemish cultivation for several crops, preparatory to that of flax, which is the most important produce in that country, and that which, when well managed, gives the greatest profit to the farmer. The best flax grows near Courtray. The soil is a good deep loam, rather light than heavy. It is not naturally so rich as the soil of the Polders in Flanders and Zealand, but the tillage and cultivation are far more perfect, and the produce, if not more abundant, is of a finer quality. Every preceding crop has a reference to the flax, and is so cultivated as to improve the texture of the soil, which is abundantly manured, in order to leave a considerable surplus in the ground. If the land has not been trenched all over with the spade, to the depth of 18 or 20 inches, it has been equally well stirred by the narrow open drains, which are dug out 12 or 15 inches deep every year, between the stitches, in which it is laid by the plough. These drains or water furrows are a foot wide, and from a foot to 18 inches deep. The earth taken out of them is spread evenly over the land after the corn is sown. When the ground is ploughed again, care is taken that the place of these water-furrows shall be shifted a foot on each side. Thus, in six years, the whole soil is deepened and thoroughly mixed with whatever manure has been put on. This produces the same effect as trenching, and even more perfectly. The whole of the land in which the best flax grows has been so treated for several generations, and may be looked upon as a species of compost 18 inches deep. Potatoes or colza are usually planted with a double portion of manure, after which wheat is sown, slightly manured; then rye with turnips sown the same year, after the rye. These are taken up in September or October, and stored for winter use. The land has been well weeded while the turnips were growing, and all the manure is decomposed and mixed with the soil. It is ploughed in stitches before winter, some manure having being previously spread over it if necessary: and it is left to the mellowing effects of frost and snow. As soon as the winter is over, and the snow is melted, the final preparation goes on. Deep ploughing and harrowing further divide and pulverize it; the surface is laid as level and as smooth as possible; and if there is no fear of too much wet, which in this light loam soon disappears, the whole is laid flat and level as a bowling-green, or else divided into beds, with water-furrows between them. On this the liquid manure is poured out, and the Dutch ashes spread, if any are used, or the rape-cakes, as mentioned before. The harrows are drawn over the land, and it is left so a few days, that the manure may sink in. It is then again harrowed, and the linseed is sown broadcast by hand, very thick, and even about 1½ cwt. to the acre. A bush harrow or a hurdle is drawn over, merely to cover the seed, which would not vegetate were it buried half an inch deep. According to the state of the land, it is rolled or not, or the seed is trodden in by men, as is done with fine seeds in gardens. This is only in the lightest soils. Most commonly the traineau is drawn over the land. This is a wooden frame with boards nailed closely over it, which is drawn flat over the ground, to level and gently press it. In a short time the plants of flax come up thick and evenly, and with them also some weeds. As soon as the flax is a few inches high, the weeds are carefully taken out by women and children, who do this work on their hands and knees, both to see the weeds better, and not to hurt the flax with their feet. They tie pieces of coarse flax round their knees, and creep on with their face to the wind if possible. This is done that the tender flax which has been bent down by creeping over it, may be assisted by the wind in rising. This shows what minute circumstances are attended to by this industrious people. The weeding is repeated till the flax is too high to allow of it.

The seed which is used is generally obtained from Riga, it being found that the flax raised from home-grown seed is inferior after the first year. But many intelligent men maintain that if a piece of ground were sown thin with linseed, so that the flax could rise with a strong stem and branch out, and if the seed were allowed to ripen, the Flemish seed would be as good as that from Riga; but it still remains to be proved whether it would be cheaper to raise it or to import it.

When the flax begins to get yellow at the bottom of the stem, it is time to pull it, if very fine flax is desired, such as is made into thread for lace or fine cambric; but then the seed will be of little or no value. It is therefore generally left standing until the capsules which contain the seed are fully grown, and the seed formed. Every flax-grower judges for himself what is most profitable on the whole. The pulling then begins, which is done carefully by small handfuls at a time. These are laid upon the ground to dry, two and two obliquely across each other. Fine weather is essential to this part of the operation. Soon after this they are collected in the larger bundles, and placed with the root end to the ground, the bundles being slightly tied near the seed end; the other end is spread out that the air may not have access, and the rain may not damage the flax. When sufficiently dry they are tied more firmly in the middle, and stacked in long narrow stacks on the ground. These stacks are built as wide as the bundles are long, and about 8 or 9 feet high. The length depends on the crop: they are seldom made above 20 or 30 feet long. If the field is extensive, several of these stacks are formed at regular distances; they are carefully thatched at top, and the ends, which are quite perpendicular, are kept up by means of two strong poles driven perpendicularly into the ground. These stacks look from a distance like short mud walls, such as are seen in Devonshire. This is the method adopted by those who defer the steeping till another season. Some carry the flax as soon as it is dry under a shed, and take off the capsules with the seed by rippling, which is drawing the flax through an iron comb fixed in a block of wood; the capsules which are too large to pass between the teeth of the comb are thus broken off and fall into a basket or cloth below. Sometimes, if the capsules are brittle, the seed is beaten out by means of a flat wooden bat, like a small cricket bat. The bundles are held by the root end, and the other end is laid on a board and turned round with the left hand while the right with the bat breaks the capsules, and the linseed falls on a cloth below. The flax may then be immediately steeped: but the most experienced flax-steepers defer this operation till the next season. In this case it is put in barns, and the seed is beat out at leisure in winter. When flax is housed, care must be taken that it be thoroughly dry; and if the seed is left on, which is an advantage to it, mice must be guarded against, for they are very fond of linseed, and would soon take away a good share of the profits by their depredations.

Steeping the flax is a very important process which requires experience and skill to do it properly. The quantity and colour depend much on the mode of steeping, and the strength of the fibre may be injured by an injurious mode of performing this operation. The object of steeping is to separate the bark from the woody part of the stem, by dissolving a glutinous matter which causes it to adhere, and also destroying some minute vessels which are interwoven with the longitudinal fibres, and keep them together in a kind of web. A certain fermentation or incipient putrefaction is excited by the steeping, which must be carefully watched and stopped at the right time. The usual mode of steeping is to place the bundles of flax horizontally in the shallow pool or ditches of stagnant water, keeping them under water by means of poles or boards with stones or weights laid upon them. Water nearly putrid was supposed the most efficacious; and the mud is often laid over the flax to accelerate the decomposition, but this has been found to stain the flax, so that it was very difficult to bleach it or the linen made from it afterwards. The method adopted by the steepers of Courtray, where steeping flax is a distinct trade, is different. The bundles of flax are placed alternately with the seeed end of the one to the root end of the other, the latter projecting a few inches; as many of these are tied together near both ends as form a thick bundle about a foot in diameter. A frame made of oak-rails nailed to strong upright pieces in the form of a box 10 feet square and 4 deep, is filled with these bundles set upright and closely packed. The whole is then immersed in the river, boards loaded with stones being placed upon the flax till the whole is sunk a little under the surface of the water. The bottom does not reach the ground, so that the water flows over and under it. There are posts driven in the river, to keep the box in its place, and each steeper has a certain portion of the bank, which is a valuable property. The flax takes somewhat longer time in steeping in this manner than it does in stagnant or putrid water, and it is asserted by those who adhere to the old method that the flax loses more weight; but the colour is so much finer, that flax is sent to be steeped in the Lys from every part of Flanders. When it is supposed that the flax is nearly steeped sufficiently, which depends on the temperature of the air, the flax being sooner steeped in warm weather than in cold, it is examined carefully every day, and towards the latter part of the time several times in the day, in order to ascertain whether the fibres really separate from the wood the whole length of the stem. As soon as this is the case the flax is taken out of the water: even a few hours more or less than is necessary will make a difference in the value of the flax. If it is not steeped enough, it will not be easily scutched, and the wood will adhere to it. If it has been too long in the water, its strength is diminished and more of it breaks into tow. The bundles are now untied, and the flax is spread evenly in rows slightly overlapping each other on a piece of clean smooth grass which has been mown or fed off close. Fine weather is essential to this part of the process, as rain would now much injure the flax. It is occasionally turned over, which is done dexterously by pushing a long slender rod under the rows, and taking up the flax near the end which overlaps the next row and turning it quite over. Thus, when it is all turned, it overlaps as before, but in the contrary direction. It remains spread out upon the grass for a fortnight, more or less according to the season, till the woody part becomes brittle, and some of the finest fibres separate from it of their own accord. It is then taken up, and as soon as it is quite dry it is tied up again in bundles, and carried into a barn to be broken and heckled at leisure during the winter.

The total annual production of flax in Belgium amounts, by a recent estimation, to about forty millions of pounds. Its total value is calculated at about two millions and a half sterling. This flax is of very superior quality, and is principally employed in the manufacture of the finest class of fabrics. Attempts are being now made on a large scale to cultivate this important plant in England and Ireland. Belgium exports about five millions of pounds of flax to England. That flax grown in the Courtray district is universally considered to be of the finest quality.

Flax Weaving Loom.—a a a, *Fig.* 648., frame of loom; b, beam on which the yarn for warp is wound; c cloth receiving beam; d driving pulleys and fly-wheel; e hand rail for supporting the reed; f swords of supports of going part; g picking sticks for driving the shuttle; h leather straps for connecting the picking sticks with their actuating levers l; m, n, jaws of a clamp to cause the retaining friction on the collars of the beam b, by which friction the quantity of weft is regulated; o end of lever, bearing the weight by which the jaws are brought together; p, lever, keyed at one end to the upright shaft q, and connected with the other to the fulcrum of the weighted lever o; r lever, one end of which is also keyed to the upright shaft q, and the other is provided with a wood sole, and is pressed by a strong spring against the yarn wound upon the beam b. It will be seen that, as the yarn is taken off the beam b, and its diameter consequently reduced, the lever p moves the fulcrum of the weighted lever o, and thus regulates the pressure upon the clamps m and n, causing an equal tension upon the yarn from the full to the empty beam; *a* treddles, actuated by the cams *b*, driven by the wheels *c, d, e*, from the picking shaft *f*; *g, g* shuttle boxes at each end of the going part; *h, h* arrangement of levers to conduct equally each end of the geers *i, i*. This loom has also, in addition to the ordinary stopping arrangement connected with the shuttle, one also for relaxing the reed in case the shuttle should be arrested in its course across the warp, whereby the danger, ordinarily incurred by that accident, of breaking many threads in the warp, is avoided; it will also be seen that the bands called picking bands are superseded by the ends of the picking levers striking the shuttle direct; thus, by these improvements, drills are currently woven in this loom at the rate of 120 to 130 picks per minute.

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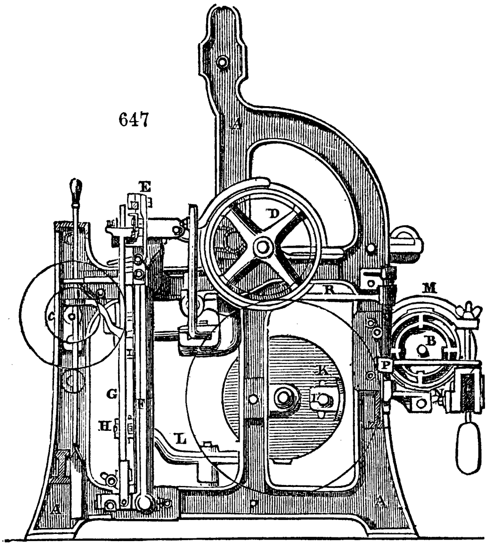
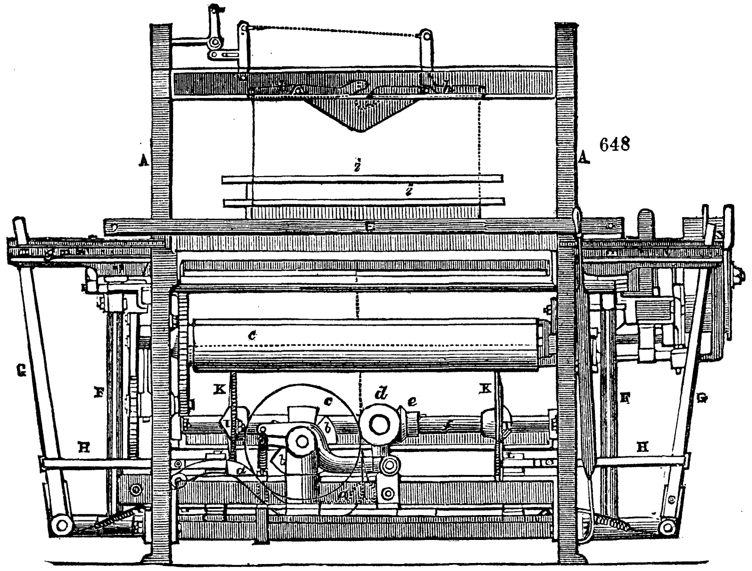


		1850	1851
Imports of flax and tow, or codilla of hemp and flax - - - - - - -	cwts.	1,822,918	1,194,184
Linen yarn exported - - - - -	lbs.	18,220,688	18,518,273
Linen manufactures exported (including linen - yarn, 881,312*l.* and 935,939*l.*) declared value -	£	4,839,779	5,053,792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FLINT. (*Pierre à fusil*, Fr.; *Feuerstein*, Germ.) The fracture of this fossil is perfectly conchoidal, sometimes glossy, and sometimes dull on the surface. It is very hard, but breaks easily, and affords very sharp-edged splintery fragments; whence it is a stone which strikes most copious sparks with steel. It is feebly translucid, has so fine and homogeneous a texture as to bear polishing, but possesses little lustre. Its colours are very various, but never vivid. The blackish-brown flint is that usually found in the white chalk. It is nearly black and opaque, loses its colour in the fire, and becomes grayish-white, and perfectly opaque. Flints occur almost always in nodules or tubercular concretions of various and very irregular forms. These nodules, distributed in strata among the chalk, alongside of one another and almost in contact, form extensive beds; interrupted, indeed, by a multitude of void spaces, so as to present, if freed from the earthy matter in which they are imbedded, a species of network with meshes, very irregular both in form and dimension.

The nodules of silex, especially those found in the chalk, are not always homogeneous and solid. Sometimes there is remarked an organic form towards their centre, as a madrepore or a shell, which seems to have served as their nucleus; occasionally the centre is hollow, and its sides are studded over with crystals of quartz, carbonate of iron, pyrites, concretionary silex or calcedony, filled with pulverulent silica nearly pure, or silex mixed with sulphur; a very singular circumstance.

Flints are observed to be generally humid when broken immediately after being dug out of the ground; a property which disappears after a short exposure to the air. When dried they become more brittle and more splintery, and sometimes their surfaces get covered at old fractures with a thin film or crust of opaque silex.

Flints calcined and ground to a powder enter into the composition of all sorts of fine pottery ware.

The next important application of this siliceous substance is in the formation of gun-flints, for which purpose it must be cut in a peculiar manner. The following characters distinguish good flint nodules from such as are less fit for being manufactured. The best are somewhat convex, approaching to globular; those which are very irregular, knobbed, branched and tuberose, are generally full of imperfection. Good nodules seldom weigh more than 20 pounds; when less than 2, they are not worth the working. They should have a greasy lustre, and be particularly smooth and fine grained. The colour may vary from honey-yellow to blackish-brown, but it should be uniform throughout the lump, and the translucency should be so great as to render letters legible through a slice about one-fiftieth of an inch thick, laid down upon the paper. The fracture should be perfectly smooth, uniform, and slightly conchoidal; the last property being essential to the cutting out of perfect gun flints.

Four tools are employed by the gun-flint makers.

First, a hammer or mace of iron with a square head, from 1 to 2 pounds weight, with a handle 7 or 8 inches long. The tool is not made of steel, because so hard a metal would render the strokes too harsh, or dry, as the workmen say, and would shatter the nodules irregularly, instead of cutting them with a clean conchoidal fracture.

Second, a hammer with 2 points, made of good steel well hardened, and weighing from 10 to 16 ounces, with a handle 7 inches long passing through it in such a way that the points of the hammer are nearer the hand of the workman than the centre of gravity of the mass.

Third, the disc hammer or roller, a small solid wheel or flat segment of a cylinder, parallel to its base, only two inches and a third in diameter, and not more than 12 ounces in weight. It is formed of steel not hardened, and is fixed upon a handle 6 inches long, which passes through a square hole in its centre.

Fourth, a chisel tapering and bevelled at both extremities, 7 or 8 inches long, and 2 inches broad, made of steel not hardened; this is set on a block of wood, which serves also for a bench to the workmen. To these 4 tools a file must be added, for the purpose of restoring the edge of the chisel from time to time.

After selecting a good mass of flint, the workman executes the four following operations on it.

1. *He breaks the block.* Being seated upon the ground, he places the nodule of flint on his left thigh, and applies slight strokes with the square hammer to divide it into smaller pieces of about a pound and a half each, with broad surfaces and almost even fractures. The blows should be moderate, lest the lump crack and split in the wrong direction.

2. *He cleaves or chips the flint.* The principal point is to split the flint well, or to chip off scales of the length, thickness, and shape adapted for the subsequent formation of gun-flints. Here the greatest dexterity and steadiness of manipulation are necessary; but the fracture of the flint is not restricted to any particular direction, for it may be chipped in all parts with equal facility.

The workman holds the lump of flint in his left hand, and strikes with the pointed hammer upon the edges of the great planes produced by the first breaking, whereby the white coating of the flint is removed in small scales, and the interior body of the flint is laid bare; after which he continues to detach similar scaly portions from the clean mass.

These scaly portions are nearly an inch and a half broad, two inches and a half long, and about one-sixth of an inch thick in the middle. They are slightly convex below, and consequently leave in the part of the lump from which they were separated a space slightly concave, longitudinally bordered by two somewhat projecting straight lines or ridges. The ridges produced by the separation of the first scales must naturally constitute nearly the middle of the subsequent pieces; and such scales alone as have their ridges thus placed in the middle are fit to be made into gun-flints. In this manner the workman continues to split or chip the mass of flint in various directions, until the defects usually found in the interior render it impossible to make the requisite fractures, or until the piece is too much reduced to sustain the smart blows by which the flint is divided.

3. *He fashions the gun-flints.* Five different parts may be distinguished in a gun-flint. 1. The sloping facet or bevel part, which is impelled against the hammer of the lock. Its thickness should be from two to three twelfths of an inch; for if it were thicker it would be too liable to break; and if more obtuse, the scintillations would be less vivid. 2. The sides, or lateral edges, which are always somewhat irregular. 3. The back or thick part opposite the tapering edge. 4. The under surface, which is smooth and rather concave. And 5. The upper face, which has a small square plane between the tapering edge and the back, for entering into the upper claw of the cock.

In order to fashion the flint, those scales are selected which have at least one of the above-mentioned longitudinal ridges; the workman fixes on one of the two tapering borders to form the striking edge, after which the two sides of the stone that are to form the lateral edges, as well as the part that is to form the back, are successively placed on the edge of the chisel in such a manner that the convex surface of the flint which rests on the forefinger of the left hand, is turned towards that tool. Then with the disc hammer he applies some slight strokes to the flint just opposite the edge of the chisel underneath, and thereby breaks it exactly along the edge of the chisel.

4. The finishing operation is the *trimming*, or the process of giving the flint a smooth and equal edge; this is done by turning up the stone and placing the edge of its tapering end upon the chisel, in which position it is completed by five or six slight strokes of the disc hammer. The whole operation of making a gun-flint, which I have used so many words to describe, is performed in less than one minute. A good workman is able to manufacture 1,000 good chips or scales in a day (if the flint-balls be of good quality),

or 500 gun-flints. Hence, in the space of three days, he can easily cleave and finish 1,000 gun-flints without any assistance.

A great quantity of refuse matter is left, for scarcely more than half the scales are good, and nearly half the mass in the best flints is incapable of being chipped out; so that it seldom happens that the largest nodules furnish more than 50 gun-flints.

Flints form excellent building materials; because they give a firm hold to the mortar by their irregularly rough surfaces, and resist, by their nature, every vicissitude of weather. The counties of Kent, Essex, Suffolk, and Norfolk, contain many substantial specimens of flint-masonry.

FLOOKAN. The name given by the Cornish miners to a vein of clay-stone, often nearly vertical.

FLOOR CLOTH MANUFACTURE has become of late years a very large branch of trade. The cloth is a strong somewhat open canvas, woven of flax with a little hemp, and from 6 to 8 yards wide, being manufactured in appropriate looms, chiefly at Dundee. A piece of this canvas, from 60 to 100 feet in length, is secured tight in an upright open frame of oaken bars, in which position it receives the foundation coats of paint, 2 or 3 in number, first on the back side, and then on the front; but it is previously brushed over with glue-size, and rubbed smooth with pumice stones. The foundation paint made with linseed oil and ochre, or any cheap colouring matter, is too thick to be applied by the brush, and is therefore spread evenly by a long narrow trowel, held in the right hand, from a patch of it laid on just before with a brush in the left hand of the workman. Each foundation coat of the front surface is smoothed by pumice whenever it is hard enough to bear the operation. When both sides are dry, the painted cloth is detached from the frame, coiled round a roller, in this state transferred to the proper printing room, where it is spread flat on a table, and variously figured and coloured devices are given to it by wooden blocks, exactly as in the block printing of calicoes, and in the wood printing of books. The blocks of the floor cloth manufacture are formed of two layers of white deal and one of pear tree timber, placed with their grain crossing one another alternately. There is of course a block for each colour in the pattern, and in each block those parts are cut away that correspond to the impression given by the others; a practice now well understood in the printing of two or more colours by the press. The faces of the blocks are so indented with fine lines, that they do not take up the paint in a heavy daub from the flat cushion on which it is spread with a brush, but in minute dots, so as to lay on the paint (somewhat thicker than that of the house painter) in a congeries of little dots or teeth, with minute interstices between. Applied in this way, the various pigments lie more evenly, are more sightly, and dry much sooner than if the prominent part of the block which takes up the colour were a smooth surface. The best kinds of floor cloth require from two to three months for their production.

FLOSS, of the puddling furnace, is the fluid glass floating upon the iron produced by the vitrification of the oxides and earths which are present.

FLOSS-SILK (*Filoselle*, *Bourre de soie*, or *fleuret*, Fr.), is the name given to the portions of ravelled silk broken off in the filature of the cocoons, which is carded like cotton or wool, and spun into a soft coarse yarn or thread, for making bands, shawls, socks, and other common silk fabrics. The floss or fleuret, as first obtained, must be steeped in water, and then subjected to pressure, in order to extract the gummy matter, which renders it too harsh and short for the spinning wheel. After being dried it is made still more pliant by working a little oil into it with the hands. It is now ready to be submitted to the carding engine. (See COTTON MANUFACTURE.) It is spun upon the flax wheel.

The female peasants of Lombardy generally wear clothes of homespun floss silk. Of late years, by improved processes, pretty fine fabrics of this material have been produced, both in England and France. M. Ajac, of Lyons, presented at one of the French national exhibitions of the objects of industry, a great variety of scarfs and square shawls, of *bourre de soie*, closely resembling those of *cachemire*.

FLOUR; the finely ground meal of wheat, and of any other corns or *cerealia*. See BREAD.

FLOUR OF WHEAT, *Adulterations of, to detect.*—The first method is by specific gravity. If potato flour be added, which is frequently done in France, since a vessel which contains one pound of wheat flour will contain one pound and a half of the fecula, the proportion of this adulteration may be easily estimated. If gypsum or ground bones be mixed with the flour, they will not only increase its density still more; but they will remain after burning away the meal.

The second method is by ascertaining the quantity of gluten which the suspected sample will afford, by the process prescribed under the article BREAD. The two following chemical criteria may also be employed.

1st. Nitric acid has the property of colouring wheat flour of a fine orange yellow whereas it affects the colour neither of fecula nor starch.

2nd. Pure muriatic acid colours good wheat flour of a deep violet, but dissolves fecula or starch, and forms with it a light, colourless, viscous fluid, decomposable by alkalis. It may also be observed, that as fecula absorbs less water than flour, this affords a ready means of detection.

The adulteration with bean or pea flour may be detected by pouring boiling water upon it, which developes the peculiar smell of these two substances.

FLOWERS (*Fleurs*, Fr.; *Blumen*, Germ.) of benzoin, of sulphur, of zinc, &c., is the appellation given by the older chemists to such substances as were obtained in a pulverulent or rather minutely crystalline form by the process of sublimation.

FLOWERS, ARTIFICIAL, MANUFACTURE OF. The art of representing by flowers, leaves, plants, &c., vegetable nature in her ornamental productions, constitutes the business of the artificial florist. The Italians appear to have been the first people in Europe who excelled in the art of making artificial flowers; but of late years the French have been most ingenious in this branch of industry.

Ribbons folded in different forms and of different colours were originally employed for imitating flowers, by being attached to wire stems. This imitation soon gave way to that by feathers, which are more delicate in texture, and more capable of assuming a variety of flower-like figures. But a great difficulty was encountered in dyeing them with due vivacity. The savages of South America manufacture perfect feather flowers, derived from the brilliant plumage of their birds, which closely resemble the products of vegetation. The blossoms and leaves are admirable, while the colours never fade.

The Italians employ frequently the cocoons of the silk-worm for this purpose; these take a brilliant dye, preserve their colour, and possess a transparent velvety appearance, suitable for petals. Of late years, the French have adopted the finest cambric for making petals, and the taffeta of Florence for the leaves. M. de Bernardiere employs whalebone in very thin leaves for artificial flowers; and by bleaching and dyeing them of various hues, he has succeeded in making his imitations of nature to be very remarkable.

The colouring matters used in flower dyeing are the following: —

For red; carmine dissolved in a solution of carbonate of potash.

For blue: indigo dissolved in sulphuric acid, diluted and neutralised in part by Spanish whitening.

For bright yellow; a solution of turmeric in spirit of wine. Cream of tartar brightens all these colours.

For violet; archil, and a blue bath.

For lilac; archil.

Some petals are made of velvet, and are coloured merely by the application of the finger dipped in the dye.

FLUATES, more properly *fluorides* (Eng. and Fr.; *Flussäure*, Germ.); compounds of fluorine and the metals; as fluor spar, for example, which consists of fluorine and calcium.

FLUOR SPAR. (*Chaux fluatée*, Fr.; *Spath fluor*, Germ.) This mineral often exhibits a variety of vivid colours. It crystallizes in the cubic system; with regular octahedral and tetrahedral cleavages; spec. grav. 3·1 to 3·2; scratches calc spar, but is scratched by a steel point; usually phosphorescent with heat; fusible at the blowpipe into an opaque head; acted on by the acids, with disengagement of a vapour which corrodes glass; its solution affords precipitates with the oxalates, but not with ammonia. Its constituents are, fluorine, 48·13; calcium, 51·87 in 100.

Fluor spar occurs subordinate to metallic veins; as to those of lead, in Derbyshire; of tin, in Saxony and Bohemia; but it is found also in masses of veins, either in crystalline rocks, associated with quartz, heavy spar, &c., as in Auvergne, Forez, Vosges, Norberg in Sweden; Norway; Petersburg; near Hall; Gourock, in Scotland, &c.; or among secondary limestones, slates, and sandstones, in Derbyshire, Cumberland, Cornwall, and New Jersey. It exists also in the amygdaloids of Scotland, and in the volcanic products of Mount Somma at Vesuvius. The variously coloured specimens, called Derbyshire spar, are worked upon the turning lathe into vases and other ornamental objects.

FLUX, (Eng. and Fr.; *Fluss*, Germ.) signifies any substance capable of promoting the fusion of earths or metallic ores by heat. White flux is the residuum of the deflagration in a red hot crucible, of a mixture of two parts of nitre, and one of cream of tartar. It is in fact merely a carbonate of potash. Black flux is obtained when equal parts of nitre and tartar are deflagrated. It owes its colour to the carbonaceous matter of the tartaric acid, which remains unconsumed; the quantity of nitre being too small for that purpose. The presence of the charcoal renders this preparation a convenient flux for reducing calcined or oxidized ores to the metallic state. Limestone, fluor-spar, borax, and several earthy or metallic oxides are employed as fluxes in metallurgy.

FLY POWDER; the black coloured powder obtained by the spontaneous oxidizement of metallic arsenic in the air.

FODDER; is the name of a weight by which lead and some other metals are sold in this country. Its varies in its amount in different parts of the kingdom; being in Northumberland estimated at 21 cwts., and in other counties 22, 23 or even more cwts.

FONDUS; is the name given by the French to a particular style of calico printing resembling the rainbow, in which the colours are graduated or melted (*fondus*) into one another, as in the prismatic spectrum. See Paper Hanging, for a description of the process.

FORGE; (Eng. and Fr.; *Feuer*, Germ.) is the name either of the furnace, where wrought iron is hammered and fashioned with the aid of heat, or the great workshop where iron is made malleable. The former is called a smith's forge, the latter a shingling mill. See Iron.

Fig. 649. represents a portable truck forge of a very commodious construction. A is the cylindric leather bellows, pressed down by a helical spring, and worked by means of the handle at B, which moves the horizontal shaft C, with its two attached semi-circular levers and chains. D, is the pipe which conducts the blast to the nozzle at E. The hearth may be covered with a thin fire-tile or with cinders. F, is a vice fixed to the strong rectangular trame. This apparatus answers all the ordinary purposes of a smith's forge; and is peculiarly adapted to ships, and to the execution of engineering jobs upon railways, or in the country. The height is 2 feet 6 inches; the length is 2 feet 9 inches; the width 2 feet. Weight about 2 cwt.

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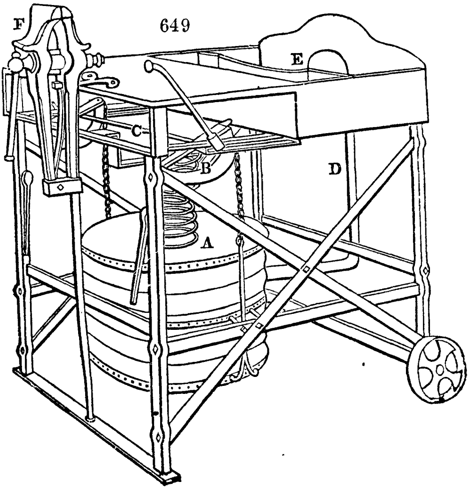

FORGERY, PREVENTION.—Forgeries of Bank cheques and other cash documents are proposed to be prevented under the patent recently granted to Messrs. Henry Glynn and Rudolph Appel. They prepare paper by mixing its pulp with solution of nitrate or sulphate of copper, to which mixture alkaline saline matter is added, to produce a cupreous precipitate (phosphate of sode being preferred), so that reddened litimus paper will be rendered blue by it. One ounce of nitrate of copper is sufficient for two gallons of the pulp, or even more if the cupreous colour is objectionable. The pulp is to be then washed with water. A mixture of equal parts of white soft soap and old palm oil is to be dissolved in boiling water, using half a pound of soap to one gallon of water. Into this saponaceous solution, the paper impregnated with the said pulp is to be dipped, and then sized. They also prevent a transfer being taken with paper, by washing it with solution of sulphate of copper, drying it, and dipping it in phosphate of soda strong enough to convert the sulphate into a phosphate.

FORMIATES; are compounds of formic acid, with the salifiable bases. Many of them are susceptible of crystallization.

FORMIC ACID, (*Acide Formique*, Fr.; *Ameisansaure*, Germ.) exists in the bodies of wood ants, associated with the malic or acid of apples. The artificial formation of this animal secretion, is one of the most remarkable triumphs of modern chemistry. If 10 parts of tartaric acid, 14 of black oxide of manganese, 15 of concentrated sulphuric acid, and from 20 to 30 of water be mixed and distilled in a retort, formic acid will be the liquid product; while carbonic acid will be disengaged. It may also be generated from other mixtures. This acid is transparent and colourless, of a pungent sour smell, a strongly acid taste, of specific gravity 1·1168 at 60° F., and may be re-distilled without suffering any change. It contains in its most concentrated form 19¾ per cent. of water. The dry acid, as it exists in the *formiates*, is composed of 32·54 carbon, 2·68 hydrogen, and 64·78 oxygen: or of two volumes carbonic oxide gas, and one volume of vapour of water. It reduces the oxides of mercury and silver to the metallic state. It has not hitherto been applied to any use in the arts.

FORMULÆ, CHEMICAL, are symbols representing the different substances, simple and compound.

Name.	Formula.	Oxygen = 100·	Hydrogen = 1.
Oxygen	O	100·000	16·026
Hydrogen	H	6·2398	1·000
	2H	12·4796	2·000
Nitrogen	N	88·518	14·186
	2N	177·086	28·372
Phosphorus	P	196·155	31·436
	2P	392·310	68·872
Chlorine	Cl	221·325	35·470
	2Cl	442·650	70·940
Iodine	I	768·781	123·206
	2I	1537·562	246·412
Carbon	C	76·437	12·250
	2C	152·875	24·500
Boron	B	135·983	21·793
	2B	271·966	43·586
Silicon	Si	277·478	44·469
Selenium	Se	494·582	79·263
Arsenic	As	470·042	75·329
	2As	940·084	150·659
Chromium	Cr	351·819	56·383
	2Cr	703·638	112·766
Molybdenum	Mo	598·525	95·920
Tungstenium	Tu or W	1183·200	189·621
Antimony	Sb	806·452	129·243
	2Sb	1612·904	258·486
Tellurium	Te	806·452	129·243
Tantalum	Ta	1153·715	184·896
	2Ta	2307·430	369·792
Titanium	Ti	389·092	62·356
Gold (aurum)	Au	1243·013	199·207
	2Au	2486·026	398·415
Platina	Pt	1215·220	194·753
Rhodium	R	750·680	120·305
	2R	1501·360	240·610
Palladium	Pd	714·618	114·526
Silver (argentum)	Ag	1351·607	216·611
Mercury (hydrargyrus)	Hg	1265·822	202·863
	2Hg	2531·645	405·725
Copper (cuprum)	Cu	395·695	63·415
	2Cu	791·390	126·829
Uranium	U	2711·360	434·527
	2U	5422·720	869·154
Bismuth	Bi	1330·376	213·208
	2Bi	2660·752	426·416
Tin (stannum)	Sn	735·294	117·839
Lead (plumbum)	Pb	1294·498	207·458
	2Pb	2588·996	414·917
Cadmium	Cd	696·767	111·665
Zinc	Zn	403·226	64·621
Nickel	Ni	369·675	59·245
Cobalt	Co	368·991	59·135
	2Co	737·982	118·270
Iron (ferrum)	Fe	339·213	54·363
	2Fe	678·426	108·725
Manganese	Mn	355·787	57·019
	2Mn	711·575	114·038
Cerium	Ce	574·718	92·105
	2Ce	1149·436	184·210
Zirconium	Zr	420·238	67·348
	2Zr	840·476	134·696
Yttrium	Y	401·840	64·395
Beryllium (glucinum)	Be	331·479	53·123
	2Be	662·958	106·247

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Name.	Formula.	Oxygen=100.	Hydrogen=1.
Aluminum	Al	171·167	27·431
	$2Al$	342·234	54·863
Magnesium	Mg	158·353	25·378
Calcium	Ca	256·019	41·030
Strontium	Sr	547·285	87·709
Barytum	Ba	856·88	137·325
Lithium	L	127·757	20·474
Natrium (sodium)	Na	290·897	46·620
	$2Na$	581·794	93·239
Kalium (potassium)	K	489·916	78·515
Ammonia	$2N\,2H_3$	214·474	34·372
Cyanogen	$2NC$	329·911	52·872
Sulphureted hydrogen	$2HS$	213·644	34·239
Hydrochloric acid	$2H\,Cl$	455·129	72·940
Hydrocyanic acid	$2HNC$	342·390	54·872
Water	$2\dot{H}$	112·479	18·026
Protoxyde of nitrogen	$2\dot{N}$	277·036	44·398
Deutoxyde of nitrogen	$\dot{N}$	188·518	30·212
Nitrous acid	$2\ddot{N}$	477·036	76·449
Nitric acid	$2\overset{\cdot:\cdot}{N}$	677·036	108·503
Hyposulphurous acid	$\dot{S}$	301·165	48·265
Sulphurous acid	$\ddot{S}$	401·165	64·291
Hyposulphuric acid	$2\overset{\cdot:\cdot}{S}$	902·330	144·609
Sulphuric acid	$\dddot{S}$	501·165	80·317
Phosphoric acid	$2\overset{\cdot:\cdot}{P}$	892·310	143·003
Chloric acid	$2\overset{\cdot:\cdot}{Cl}$	942·650	151·071
Perchloric acid	$2\overset{:::}{Cl}$	1042·650	167·097
Iodic acid	$2\overset{\cdot:\cdot}{I}$	2037·562	326·543
Carbonic acid	$\ddot{C}$	276·437	44·302
Oxalic acid	$2\dddot{C}$	452·875	72·578
Boracic acid	$2\overset{:::}{B}$	871·966	139·743
Silicic acid	$\dddot{Si}$	577·478	92·548
Selenic acid	$\ddot{Se}$	694·582	111·315
Arsenic acid	$2\overset{\cdot:\cdot}{As}$	1440·084	230·790
Protoxyde of chrome	$2\dddot{Cr}$	1003·638	160·840
Chromic acid	$\dddot{Cr}$	651·819	104·462
Molybdic acid	$\dddot{Mo}$	898·525	143·999
Tunstic, or wolfram acid	$\dddot{W}$	1483·200	237·700
Oxyde of antimony	$2\dddot{Sb}$	1912·904	306·565
Antimonious acid	$\ddot{Sb}$	1006·452	161·296
	$2\ddot{Sb}$	2012·904	322·591
Antimonic acid	$2\overset{\cdot:\cdot}{Sb}$	2112·904	338·617

Name.	Formula.	Oxygen=100.	Hydrogen=1
Oxyde of tellurium . .	$\ddot{\mathrm{Te}}$	1006·452	161·296
Tantalic acid . . .	$2\dddot{\mathrm{Ta}}$	2607·430	417·871
Titanic acid . . .	$\ddot{\mathrm{Ti}}$	589·092	94·409
Protoxyde of gold . .	$2\dot{\mathrm{Au}}$	2586·026	414·441
Peroxyde of gold . .	$2\dddot{\mathrm{Au}}$	2786·026	446·493
Oxyde of platina . .	$\ddot{\mathrm{Pt}}$	1415·220	226·086
Oxyde of rhodium . .	$2\dddot{\mathrm{R}}$	1801·360	228·689
Oxyde of palladium . .	$\dot{\mathrm{Pd}}$	814·618	130·552
Oxyde of silver . .	$\dot{\mathrm{Ag}}$	1451·607	232·637
Protoxyde of mercury .	$2\dot{\mathrm{Hg}}$	2631·645	421·752
Peroxyde of mercury . .	$\dot{\mathrm{Hg}}$	1365·822	218·889
Protoxyde of copper . .	$2\dot{\mathrm{Cu}}$	801·390	142·856
Peroxyde of copper . .	$\dot{\mathrm{Cu}}$	495·695	79·441
Protoxyde of uranium . .	$\dot{\mathrm{U}}$	2811·360	450·553
Peroxyde of uranium . .	$2\dddot{\mathrm{U}}$	5722·720	917·132
Oxyde of bismuth . .	$2\dddot{\mathrm{Bi}}$	2960·752	474·49
Protoxyde of tin . .	$\dot{\mathrm{Sn}}$	835·294	133·866
Peroxyde of tin . .	$\ddot{\mathrm{Sn}}$	935·294	149·892
Oxyde of lead . . .	$\dot{\mathrm{Pb}}$	1394·498	223·484
Minium . . .	$2\dddot{\mathrm{Pb}}$	2888·996	462·995
Brown oxyde of lead . .	$\ddot{\mathrm{Pb}}$	1494·498	239·511
Oxyde of cadmium . .	$\dot{\mathrm{Cd}}$	796·767	127·691
Oxyde of zinc . .	$\dot{\mathrm{Zn}}$	503·226	80·649
Oxyde of nickel . .	$\dot{\mathrm{Ni}}$	469·675	75·271
Oxyde of cobalt . .	$\dot{\mathrm{Co}}$	468·991	75·161
Peroxyde of cobalt . .	$2\dddot{\mathrm{Co}}$	1037·982	166·349
Protoxyde of iron . .	$\dot{\mathrm{Fe}}$	439·213	70·389
Peroxyde of iron . .	$2\dddot{\mathrm{F}}$	978·426	156·804
Protoxyde of manganese .	$\dot{\mathrm{Mn}}$	455·787	73·045
Oxyde of manganese . .	$2\dddot{\mathrm{Mn}}$	1011·575	162·117
Peroxyde of manganese .	$\ddot{\mathrm{Mn}}$	555·787	89·071
Manganesic acid . .	$2\overset{\cdot\;\cdot\;\cdot}{\dddot{\mathrm{Mn}}}$	1211·575	194·169
Protoxyde of cerium . .	$\dot{\mathrm{Ce}}$	674·718	108·132
Oxyde of cerium . .	$2\dddot{\mathrm{Ce}}$	1449·436	232·289
Zirconia . . .	$2\dddot{\mathrm{Zr}}$	1140·476	182·775
Yttria . . .	$\dot{\mathrm{Y}}$	501·840	80·425
Glucina, or berryllia . .	$2\dddot{\mathrm{Be}}$	962·958	154·325

Name	Formula.	Oxygen=100.	Hydrogen=1.
Alumina . . .	$2\dddot{Al}$	642·334	109·942
Magnesia . .	Mg	258·353	41·404
Lime	$\dot{Ca}$	356·019	57·056
Strontia . . .	$\dot{Sr}$	647·285	103·735
Baryta . . .	$\dot{Ba}$	956·880	153·351
Lithia . . .	$\dot{L}$	227·757	36·501
Natron, or soda . .	$\dot{Na}$	390·897	62·646
Peroxyde of sodium . .	$2\dddot{Na}$	881·794	141·318
Kali, or potassa . .	$\dot{K}$	589·916	94·541
Peroxyde of potassium .	$\dddot{K}$	789·916	126·593
Sulphate of potassa . .	$\dot{K}\,\dddot{S}$	1091·081	174·859
Protosulphate of iron . .	$\dot{Fe}\,\dddot{S}$	940·378	150·706
Persulphate of iron . .	$2\ddot{Fe}\,\dddot{S}_3$	2481·906	397·754
Protochloride of iron . .	$Fe\ 2Cl$	781·863	125·303
Perchloride of iron . .	$2Fe\ 2Cl_3$	2006·376	321·545
Protochloride of mercury .	$2Hg\ 2Cl$	2974·295	476·666
Perchloride of mercury .	$Hg\ 2Cl$	1708·472	273·803
Ferrocyanide of iron . .	$Fe\ 2NC+2K\ 2NC$	2308·778	370·008
Alum	$\dot{K}\,\dddot{S}+2\dddot{Al}\,\dddot{S}_3+24\ 2\dot{H}$	5936·406	951·378
Feldspar . . .	$\dot{K}\,\dddot{Si}+2\dddot{Al}\,\dddot{Si}_3$	3542·162	567·673

FOUNDING *of metals, chiefly of Iron.* The operations of an iron foundry consist in re-melting the pig-iron of the blast furnaces, and giving it an endless variety of forms, by casting it in moulds of different kinds, prepared in appropriate manners. Coke is the only kind of fuel employed to effect the fusion of the cast-iron.

The essential parts of a well-mounted iron foundry are,

1. Magazines for pig-irons of different qualities, which are to be mixed in certain proportions, for producing castings of peculiar qualities; as also for coal, coke, sands, clay, powdered charcoal, and cow-hair for giving tenacity to the loam mouldings.
2. One or more coke ovens.
3. A workshop for preparing the patterns and materials of the moulds. It should contain small edge millstones for grinding and mixing the loam, and another mill for grinding coal and charcoal.
4. A vast area, called properly the foundry, in which the moulds are made and filled with the melted metal. These moulds are in general very heavy, consisting of two parts at least, which must be separated, turned upside down several times, and replaced very exactly upon one another. The casting is generally effected by means of large ladles or pots, in which the melted iron is transported from the cupola, where it is fused. Hence, the foundry ought to be provided with cranes, having jibs moveable in every direction.
5. A stove in which such moulds may be readily introduced as require to be entirely deprived of humidity, and where a strong heat may be uniformly maintained.
6. Both blast and air furnaces, capable of melting speedily the quantity of cast-iron to be employed each day.
7. A blowing machine to urge the fusion in the furnaces.

Fig. 650 represents the general plan of a well-mounted foundry.

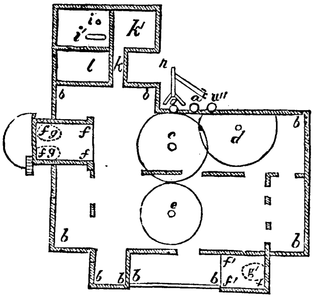
a is a cupola furnace, of which the section and view will be afterwards given; it is capable of containing 5 tons of cast-iron.

a' is a similar furnace, but of smaller dimensions, for bringing down 1¾ tons.

a'' is a furnace like the first, in reserve for great castings.

b, b, b, b, a vast foundry apartment, whose floor, to a yard in depth, is formed of sand and charcoal powder, which have already been used for castings, and are ready for heaping up into a substratum, or to be scooped out when depth is wanted for the moulds. There are besides several cylindrical pits, from five to seven yards in depth, placed near the furnaces. They are lined with brick work, and are usually left full of moulding sand. They are emptied in order to receive large moulds, care being had that their top is always below the orifice from which the melted metal is tapped.

650



These moulds, and the ladles full of melted metal, are lifted and transported by the arm of one or more men, when their weight is moderate; but if it be considerable, they are moved about by cranes whose vertical shafts are placed at *c*, *d*, *e*, in correspondence, so that they may upon occasion transfer the load from one to another. Each crane is composed principally of an upright shaft, embraced at top by a collet, and turning below upon a pivot in a step; next of a horizontal beam, stretched out from nearly the top of the former, with an oblique stay running downwards, like that of a gallows. The horizontal beam supports a moveable carriage, to which the tackle is suspended for raising the weights. This carriage is made to glide backwards or forwards along the beam by means of a simple rack and pinion mechanism, whose long handle descends within reach of the workman's hand.

By these arrangements in the play of the three cranes, masses weighing five tons may be transported and laid down with the greatest precision upon any point whatever in the interior of the three circles traced upon *fig.* 650 with the points *c*, *d*, *e*, as centres.

c, *d*, *e*, are the steps, upon which the upright shafts of the three cranes rest and turn. Each shaft is 16 feet high.

f, *f*, is the drying stove, having its floor upon a level with that of the foundry.

f', *f'*, is a supplementary stove for small articles.

g, *g*, *g*, are the coking ovens.

h, is the blowing machine or fan.

i, is the steam-engine, for driving the fan, the loam-edge stones,

k, and the charcoal mill.

i'', are the boiler and the furnace of the engine.

k', workshop for preparing the loam and other materials of moulding.

l, is the apartment for the patterns.

The pig-iron, coals, &c. are placed either under sheds or in the open air, round the above buildings; where are also a smith's forge, a carpenter's shop, and an apartment mounted with vices for chipping and rough cleaning the castings by chisels and files.

Such a foundry may be erected upon a square surface of about 80 yards in each side, and will be capable, by casting in the afternoon and evening of each day, partly in large and partly in small pieces, of turning out from 700 to 800 tons per annum, with an establishment of 100 operatives, including some moulding boys.

Of making the moulds.—1. Each mould ought to present the exact form of its object.

2. It should have such solidity that the melted metal may be poured into it, and fill it entirely without altering its shape in any point.

3. The air which occupies the vacant spaces in it, as well as the carbureted gases generated by the heat, must have a ready vent; for if they are but partially confined, they expand by the heat, and may crack, even blow up the moulds, or at any rate become dispersed through the metal, making it vesicular and unsound.

There are three distinct methods of making the moulds :—

1. In green sand; 2. In baked sand; 3. In loam.

To enumerate the different means employed to make every sort of mould exceeds the limits prescribed to this work. I shall merely indicate for each species of moulding, what is common to all the operations ; and I shall then describe the fabrication of a few such moulds as appear most proper to give general views of this peculiar art.

Moulding in green sand.—The name green is given to a mixture of the sand as it comes from its native bed, with about one twelfth its bulk of coal reduced to powder, and damped in such a manner as to form a porous compound, capable of preserving the forms of the objects impressed upon it. This sand ought to be slightly argillaceous, with particles not exceeding a pin's head in size. When this mixture has once served for a mould, and been filled with metal, it cannot be employed again except for the coarsest castings, and is generally used for filling up the bottoms of fresh moulds.

For moulding any piece in green sand, an exact pattern of the object must be prepared in wood or metal; the latter being preferable, as not liable to warping, swelling, or shrinkage.

A couple of iron frames form a case or box, which serves as an envelope to the mould Such boxes constitute an essential and very expensive part of the furniture of a foundry It is a rectangular frame, without bottom or lid, whose two largest sides are united by a series of cross bars, parallel to each other, and placed from 6 to 8 inches apart.

The two halves of the box carry ears corresponding exactly with one another; of which one set is pierced with holes, but the other has points which enter truly into these holes, and may be made fast in them by cross pins or wedges, so that the pair becomes one solid body. Within this frame there is abundance of room for containing the pattern of the piece to be moulded with its incasing sand, which being rammed into the frame, is retained by friction against the lateral faces and cross bars of the mould.

When a mould is to be formed, a box of suitable dimensions is taken asunder, and each half, No. 1 and No. 2, is laid upon the floor of the foundry. Green sand is thrown with a shovel into No. 1, so as to fill it; when it is gently pressed in with a rammer. The object of this operation is to form a plain surface upon which to lay in the pattern with a slight degree of pressure, varying with its shape. No. 1 being covered with sand, the frame No. 2 is laid upon it, so as to form the box. No. 2 being now filled carefully with the green sand, the box is inverted, so as to place No. 1 uppermost, which is then detached and lifted off in a truly vertical position; carrying with it the body of sand formed at the commencement of the operation. The pattern remains imbedded in the sand of No. 2, which has been exactly moulded upon a great portion of its surface. The moulder condenses the sand in the parts nearest to the pattern, by sprinkling a little water upon it, and trimming the ill-shaped parts with small iron trowels of different kinds. He then dusts a little well-dried finely-sifted sand over all the visible surface of the pattern, and of the sand surrounding it; this is done to prevent adhesion when he replaces the frame No. 1.

He next destroys the preparatory smooth bed or area formed in this frame, covers the pattern with green sand, replaces the frame 1 upon 2, to reproduce the box, and proceeds to fill and ram No. 1, as he had previously done No. 2. The object of this operation is to obtain very exactly a concavity in the frame No. 1, having the shape of the part of the model impressed coarsely upon the surface formed at the beginning, and which was meant merely to support the pattern and the sand sprinkled over it, till it got imbedded in No. 2.

The two frames in their last position, along with their sand, may be compared to a box of which No. 1 is the lid, and whose interior is adjusted exactly upon the enclosed pattern.

If we open this box, and after taking out the pattern, close its two halves again, then pour in melted metal till it fill every void space, and become solid, we shall obviously attain the wished-for end, and produce a piece of cast iron similar to the pattern. But many precautions must still be taken before we can hit this point. We must first lead through the mass of sand in the frame No. 1 one or more channels for the introduction of the melted metal; and though one may suffice for this purpose, another must be made for letting the air escape. The metal is run in by several orifices at once, when the piece has considerable surface, but little thickness, so that it may reach the remotest points sufficiently hot and liquid.

The parts of the mould near the pattern must likewise be pierced with small holes, by means of wires traversing the whole body of the sand, in order to render the mould more porous, and to facilitate the escape of the air and the gases. Then, before lifting off the frame No. 1, we must tap the pattern slightly, otherwise the sand enclosing it would stick to it in several points, and the operation would not succeed. These gentle jolts are given by means of one or more pieces of iron wire which have been screwed vertically into the pattern before finally ramming the sand into the frame No. 1, or which enter merely into holes in the pattern. These pieces are sufficiently long to pass out through the sand when the box is filled; and it is upon their upper ends that the horizontal blows of the hammer are given; their force being regulated by the weight and magnitude of the pattern. These rods are then removed by drawing them straight out; after which the frame No. 1 may be lifted off smoothly from the pattern.

The pattern itself is taken out, by lifting it in all its parts at once, by means of screw pins adjusted at the moment. This manœuvre is executed, for large pieces, almost always by several men, who, while they lift the pattern with one hand, strike it with the other with small repeated blows to detach the sand entirely, in which it is generally more engaged than it was in that of the frame No. 1. But in spite of all these precautions, there are always some degradations in one or other of the two parts of the mould; which are immediately repaired by the workman with damp sand, which he applies and presses gently with his trowel, so as to restore the injured forms.

Hitherto I have supposed all the sand rammed into the box to be of one kind; but

From economy, the green sand is used only to form the portion of the mould next the pattern, in a stratum of about an inch thick; the rest of the surrounding space is filled with the sand of the floor which has been used in former castings. The interior layer round the pattern is called, in this case, *new sand.*

It may happen that the pattern is too complex to be taken out without damaging the mould, by two frames alone; then 3 or more are mutually adjusted to form the box.

When the mould, taken asunder into two or more parts, has been properly repaired, its interior surface must be dusted over with wood charcoal reduced to a very fine powder, and tied up in a small linen bag, which is shaken by hand. The charcoal is thus sifted at the moment of application, and sticks to the whole surface, which has been previously damped a little. It is afterwards polished with a fine trowel. Sometimes, in order to avoid using too much charcoal, the surfaces are finally dusted over with sand, very finely pulverized, from a bag like the charcoal. The two frames are now replaced with great exactness, made fast together by the ears, with wedged bolts laid truly level, or at the requisite slope, and loaded with considerable weights. When the casting is large, the charcoal dusting, as well as that of fine sand, is suppressed. Everything is now ready for the introduction of the fused metal.

Moulding in baked or used sand.—The mechanical part of this process is the same as of the preceding. But when the castings are large, and especially if they are tall, the hydrostatic pressure of the melted metal upon the sides of the mould cannot be counteracted by the force of cohesion which the sand acquires by ramming. We must in that case adapt to each of these frames a solid side, pierced with numerous small holes to give issue to the gases. This does not form one body with the rest of the frame, but is attached extemporaneously to it by bars and wedged bolts. In general, no ground coal is mixed with this sand. Whenever the mould is finished, it is transferred to the drying stove, where it may remain from 12 to 24 hours at most, till it be deprived of all its humidity. The sand is then said to be baked or annealed. The experienced moulder knows how to mix the different sands placed at his disposal, so that the mass of the mould as it comes out of the stove may preserve its form, and be sufficiently porous. Such moulds allow the gases to pass through them much more readily than those made of *green* sand; and in general the castings they turn out are less vesicular, and smoother upon the surface. Sometimes in a large piece, the three kinds of moulding, that in green sand, in baked sand, and in loam, are combined to produce the best result.

Moulding in loam.—This kind of work is executed from drawings of the pieces to be moulded, without being at the expense of making patterns. The mould is formed of a pasty mixture of clay, water, sand, and cow's-hair, or other cheap filamentous matter, kneaded together in what is called the loam mill. The proportions of the ingredients are varied to suit the nature of the casting. When the paste requires to be made very light, horse dung or chopped straw is added to it.

I shall illustrate the mode of fabricating loam moulds, by a simple case, such as that of a sugar pan. *Fig.* 651 is the pan. There is laid upon the floor of the foundry an annular platform of cast-iron, *a b*, *fig.* 652; and upon its centre *c*, rests the lower extremity of a vertical shaft, adjusted so as to turn freely upon itself, while it makes a wooden pattern, *e f*, *fig.* 653, describe a surface of revolution identical with the internal surface reversed of the boiler intended to be made. The outline, *e g*, of the pattern is fashioned so as to describe the surface of the edge of the vessel. Upon the part *a d b d*, *fig.* 652, of the flat cast-iron ring, there must next be constructed, with bricks laid either flat or on their edge, and clay, a kind of dome, *h i k*, *fig.* 653, from two to four inches thick, according to the size and weight of the piece to be moulded. The external surface of the brick dome ought to be everywhere two inches distant, at least, from the surface described by the arc *e f*. Before building up the dome to the point *i*, coals are to be placed in its inside upon the floor, which may be afterwards kindled for drying the mould. The top is then formed, leaving at *i*, round the upright shaft of revolution, only a very small outlet. This aperture, as also some others left under the edges of the iron ring, enable the moulder to light the fire when it becomes necessary, and to graduate it so as to make it last long enough without needing more fuel, till the mould be quite finished and dry. The combustion should be always extremely slow.

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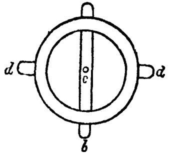

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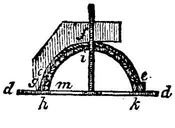

Over the brick dome a pasty layer of loam is applied, and rounded with the mould *g e f;* this surface is then coated with a much smoother loam, by means of the concave edge of the same mould. Upon the latter surface, the inside of the sugar pan is cast; the line *e g* having traced, in its revolution, a ledge *m*. The fire is now kindled, and as the surface of the mould becomes dry, it is painted over by a brush, with a mixture of water, charcoal powder, and a little clay, in order to prevent adhesion between the surface already dried and the coats of clay about to be applied to it. The board *g e f* is now removed, and replaced by another, *g′ e′ f′*, *fig.* 654, whose edge *e′ f′* describes the outer surface of the pan. Over the surface *e*, *f*, a layer of loam is applied, which is turned and polished so as to produce the surface of revolution *e′ f′*, as was done for the surface *e f;* only in the latter case, the line *e′ g′* of the board does not form a new shoulder, but rubs lightly against *m*.

The layer of loam included between the two surfaces *e f*, *e′ f′*, is an exact representation of the sugar pan. When this layer is well dried by the heat of the interior fire, it must be painted like the former. The upright shaft is now removed, leaving the small vent hole through which it passed to promote the complete combustion of the coal. There must be now laid horizontally upon the ears of the platform *d d*. *fig.* 652, another annular platform *p q*, like the former, but a little larger, and without any cross-bar.

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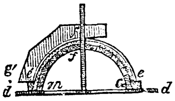

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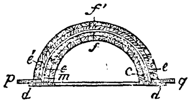

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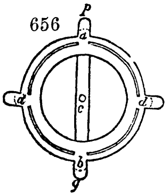

The relative position of these two platforms is shown in *fig.* 656. Upon the surface *e′ f′*, *fig.* 655, a new layer of loam is laid, two inches thick, of which the surface is smoothed by hand. Then upon the platform *p q*, *fig.* 656, a brick vault is constructed, whose inner surface is applied to the layer of loam. This contracts a strong adherence with the bricks which absorb a part of its moisture, while the coat of paint spread over the surface *e′ f′*, prevents it from sticking to the preceding layers of loam. The brick dome ought to be built solidly.

The whole mass is now to be thoroughly dried by the continuance of the fire, the draught of which is supported by a small vent left in the upper part of the new dome; and when all is properly dry, the two iron platforms are adjusted to each other by pin points, and *p q* is lifted off, taking care to keep it in a horizontal position. Upon this platform are removed the last brick dome, and the layer of loam which had been applied next to it; the latter of which represents exactly by its inside the mould of the surface *e′ f′*, that is, of the outside of the pan. The crust contained between *e f* and *e′ f′* is broken away, an operation easily done without injury to the surface *e f*, which represents exactly the inner surface of the pan; or only to the shoulder *m*, corresponding to the edge of the vessel. The top aperture through which the upright shaft passed must be now closed; only the one is kept open in the portion of the mould lifted off upon *p q;* because through this opening the melted metal is to be poured in the process of casting. The two platforms being replaced above each other very exactly, by means of the adjusting pin points, the mould is completely formed, and ready for the reception of the metal.

When the object to be moulded presents more complicated forms than the one now chosen for the sake of illustration, it is always by analogous processes that the workman constructs his loam moulds, but his sagacity must hit upon modes of executing many things which at first sight appear to be scarcely possible. Thus, when the forms of the interior and exterior do not permit the mould to be separated in two pieces, it is divided into several, which are nicely fitted with adjusting pins. More than two cast-iron rings or platforms are sometimes necessary. When ovals or angular surfaces must be traced instead of those of revolution, no upright shaft is used, but wooden or cast-iron guides made on purpose, along which the pattern cut-out board is slid according to the drawing of the piece. Iron wires and claws are often interspersed through the brick work to give it cohesion. The core, kernel, or inner mould of a hollow casting is frequently fitted in when the outer shell is moulded. I shall illustrate this matter in the case of a gas-light retort, *fig.* 657. The core of the retort ought to have the form *e e e e*, and be very solid, since it cannot be fixed in the outer mould, for the casting, except in the part standing out of the retort towards *m m*. It must be modelled in loam, upon a piece of cast-iron called a *lantern*, made expressly for this purpose. The lantern is a cylinder or a truncated hollow cone of cast-iron, about half an inch thick; and differently shaped for every different core. The surface is perforated with holes of about half an inch in diameter. It is mounted by means of iron cross-bars, upon an iron axis, which traverses it in the direction of its length. *Fig.* 658 represents a horizontal section through the axis of the core; *g h* is the axis of the lantern, figured itself at *i k*

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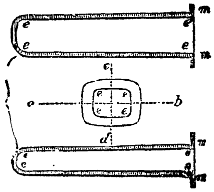

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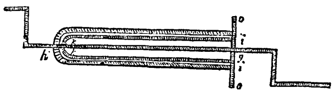

k i; *o i i o* is a kind of disc or dish, perpendicular to the axis, open at *i i*, forming one piece with the lantern, whose circumference *o o* presents a curve similar to the section of the core, made at right angles to its axis. We shall see presently the two uses for which this dish is intended. The axis *g h* is laid upon two gudgeons, and handles are placed at each of its extremities, to facilitate the operation in making the core. Upon the whole surface of the lantern, from the point *h* to the collet formed by the dish a hay cord as thick as the finger is wound. Even two or more coils may be applied, as occasion requires, over which loam is spread to the exact form of the core, by applying with the hand a board, against the dish *o o*, with its edge cut out to the desired shape; as also against another dish, adjusted at the time towards *h*; while by means of the handles a rotatory movement is given to the whole apparatus.

The hay interposed between the lantern and the loam, which represents the crust of the core, aids the adhesion of the clay with the cast-iron of the lantern, and gives passage to the holes in its surface, for the air to escape through in the casting.

When the core is finished, and has been put into the drying stove, the axis *g h* is taken out, then the small opening which it leaves at the point *h*, is plugged with clay. This is done by supporting the core by the edges of the dish, in a vertical position. It is now ready to be introduced into the hollow mould of the piece.

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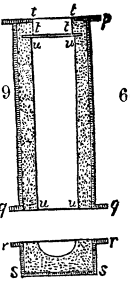

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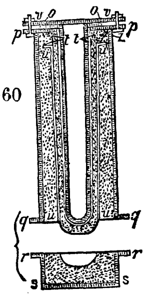

This mould executed in baked sand consists of three pieces, two of which, absolutely similar, are represented, *fig.* 659, at *p q*, the third is shown at *r s*. The two similar parts *p q*, present each the longitudinal half of the nearly cylindrical portion of the outer surface of the gas retort; so that when they are brought together, the cylinder is formed; *r s* contains in its cavity the kind of hemisphere which forms the bottom of the retort. Hence, by adding this part of the mould to the end of the two others, the resulting apparatus presents in its interior, the exact mould of the outside of the retort; an empty cylindrical portion *t t*, whose axis is the same as that of the cylinder *u u*, and whose surface, if prolonged, would be everywhere distant from the surface *u u*, by a quantity equal to the desired thickness of the retort. The diameter of the cylinder *t t* is precisely equal to that of the core, which is slightly conical, in order that it may enter easily into this aperture *t t*, and close it very exactly when it is introduced to the collet or neck.

The three parts of the mould and the core being prepared, the two pieces *p q*, must first be united, and supported in an upright position; then the core must be let down into the opening *t t*, *fig.* 660. When the plate or disc *o o* of the core is supported upon the mould, we must see that the end of the core is everywhere equally distant from the edge of the external surface *u u*, and that it does not go too far beyond the line *q q*. Should there be an inaccuracy, we must correct it by slender iron slips placed under the edge of the disc *o o*; then by means of a cast-iron cross, and screw bolts *v v*, we fix the core immoveably. The whole apparatus is now set down upon *r s*, and we fix with screw bolts the plane surface *q q* upon *r r*; then introduce the melted metal by an aperture *z*, which has been left at the upper part of the mould.

When, instead of the example now selected, the core of the piece to be cast must go beyond the mould of the external surface, as is the case with a pipe open at each end, the thing is more simple, because we may easily adjust and fix the core by its two ends.

In casting a retort, the metal is poured into the mould set upright. It is important to maintain this position in the two last examples of casting; for all the foreign matters which may soil the metal during its flow, as the sand, the charcoal, gases, scoriæ, being less dense than it, rise constantly to the surface. The hydrostatic pressure produced by a high gate, or filling-in aperture, contributes much to secure the soundness and solidity of the casting. This gate-piece being superfluous, is knocked off almost immediately after, or even before the casting cools. Very long, somewhat slender pieces, are usually cast in moulds set up obliquely to the horizon. As the metal shrinks in cooling, the mould should always be somewhat larger than the object intended to be cast. The iron founder reckons in general upon a linear shrinkage of a ninety-sixth part; that is, one eighth of an inch per foot.

Melting of the cast iron.—The metal is usually melted in a cupola furnace, of which the dimensions are very various. *Fig.* 661 represents in plan, section, and elevation, one of these furnaces of the largest size; being capable of founding 5 tons of cast iron at a time. It is kindled by laying a few chips of wood upon its bottom, leaving the orifice *c* open, and it is then filled up to the throat with coke. The fire is lit at *c*, and in a quarter or half an hour, when the body of fuel is sufficiently kindled, the tuyère blast is set in action. The flame issues then by the mouth as well as the orifice *c*, which has been left open on purpose to consolidate it by the heat. Without this precaution, the sides, which are made up in argillaceous sand after each day's work, would not present the necessary resistance. A quarter of an hour afterwards, the orifice *c* is closed with a lump of moist clay, and sometimes, when the furnace is to contain a great body of melted metal, the clay is supported by means of a small plate of cast iron fixed against the furnace. Before the blowing machine is set a going, the openings *g g g* had been kept shut. Those of them wanted for the tuyères are opened in succession, beginning at the lowest, the tuyères being raised according as the level of the fused iron stands higher in the furnace. The same cupola may receive at a time from one to six tuyères, through which the wind is propelled by the centrifugal action of an eccentric fan or ventilator. It does not appear to be ascertained whether there be any advantage in placing more than two tuyères facing each other upon opposite sides of the furnace. Their diameter at the nozzle varies from 3 to 5 inches. They are either cylindrical or slightly conical. A few minutes after the tuyères have begun to blow, when the coke sinks in the furnace, alternate charges of coke and pig iron must be thrown in. The metal begins to melt in about 20 minutes after its introduction; and successive charges are then made every 10 minutes nearly; each charge containing from 2 cwts. to 5 cwts. of iron, and a quantity proportional to the estimate given below. The amount of the charges varies of course with the size of the furnace, and the speed required for the operation. The pigs must be previously broken into pieces weighing at most 14 or 16 pounds. The vanes of the blowing fan make from 625 to 650 turns per minute. The two cupolas represented *fig.* 661, and another alongside in the plan, may easily melt 6½ tons of metal in 2¾ hours; that is, 2⅓ tons per hour This result is three or four times greater than what was

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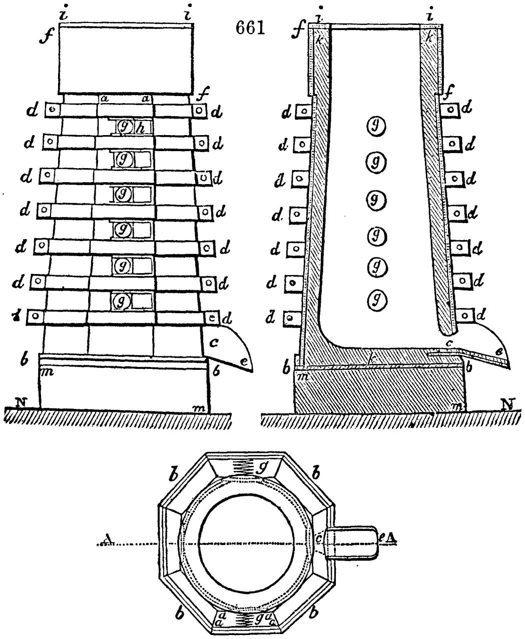

formerly obtained in similar cupolas, when the blast was thrown in from small nozzles with cylinder bellows, moved by a steam engine of 10 horse power.

In the course of a year, a considerable foundry like that represented in the plan, *fig*. 650, will consume about 300 tons of coke in melting 1240 tons of cast iron; consisting of 940 tons of pigs of different qualities, and 300 tons of broken castings, gate-pieces, &c. Thus, it appears that 48 pounds of coke are consumed for melting every 2 cwt. of metal.

Somewhat less coke is consumed when the fusion is pushed more rapidly to collect a great body of melted metal, for casting heavy articles; and more is consumed when, as in making many small castings, the progress of the founding has to be slackened from time to time; otherwise, the metal would remain too long in a state of fusion, and probably become too cold to afford sharp impressions of the moulds.

It sometimes happens that in the same day, with the same furnace, pieces are to be cast containing several proportions of different kinds of iron; in which case, to prevent an intermixture with the preceding or following charges, a considerable bed of coke is interposed. Though there be thus a little waste of fuel, it is compensated by the improved adaptation of the castings to their specific objects. The founding generally begins at about 3 o'clock, P. M., and goes on till 6 or 8 o'clock. One founder, aided by four laborers for charging, &c., can manage two furnaces.

The following is the work of a well-managed foundry in Derby.

200 lbs. of coke are requisite to melt, or bring down (in the language of the founders), 1 ton of cast-iron, after the cupola has been brought to its proper heat, by the combustion in it of 9 baskets of coke, weighing, by my trials, 40 pounds each, = 360 lbs.

The chief talent of the founder consists in discovering the most economical mixtures, and so compounding them as to produce the desired properties in the castings. One piece, for example, may be required to have great strength and tenacity to bear heavy weights or strains; another must yield readily to the chisel or the file; a third must resist sudden alternations of temperature; and a fourth must be pretty hard.

The filling in of the melted metal is managed in two ways. For strong pieces, whose moulds can be buried in the ground at 7 or 8 yards distance from the furnace, the metal may be run in gutters, formed in the sand of the floor, sustained by plates or stones. The clay plug is pierced with an iron rod, when all is ready.

When from the smaller size, or greater distance of the moulds, the melted metal cannot be run along the floor from the furnace, it is received in cast-iron pots or ladles, lined with a coat of loam. These are either carried by the hands of two or more men, or transported by the crane. Between the successive castings, the discharge hole of the furnace is closed with a lump of clay, applied by means of a stick, having a small disc of iron fixed at its end.

After the metal is somewhat cooled, the moulds are taken asunder, and the excrescences upon the edges of the castings are broken off with a hammer. They are afterwards more carefully trimmed or chipped by a chisel when quite cold. The loss of weight in founding is about 6½ per cent. upon the pig iron employed. Each casting always requires the melting of considerably more than its own weight of iron. This excess forms the gates, false seams, &c.; the whole of which being deducted, shows that 1 cwt. of coke is consumed for every 3 cwts. of iron put into the furnace; for every 138 cwts. of crude metal, there will be 100 cwts. of castings, 32 of refuse pieces, and 6 of waste.

Explanation of the plates.

Manner of constructing the Mould of a Sugar-pan.

Fig. 651. View of the pan.
— 652. Flat ring of cast-iron for supporting the inner mould.
— 653. Construction of the inner mould.
— 654. Formation of the outer surface of the pan.
— 655. Finished mould.
— 656. Position of the two flat cast-iron rings, destined to sustain the moulds of the inner and the outer surface.

Gas-retort Moulding.

— 657. Vertical projection, perpendicular to the axis of the retort; and two sections the one upright, the other horizontal.
— 658. Construction of the core of the retort.
— 659. Disposition of the outer mould.
— 660. Adjustment of the core in the mould.
— 661. *Cupola furnace*. It is 3 feet wide within, and 13½ high.
m m, solid body of masonry, as a basis to the furnace.

b b, octagonal platform of cast iron, with a ledge in which the plates *a a a a* are engaged.

a a, eight plates of cast iron, 1 inch thick, absolutely similar; only one of them is notched at its lower part in *c*, to allow the melted metal to run out, and two of the others have six apertures *g g g*, &c. to admit the tuyères.

c, orifice for letting the metal flow out. A kind of cast iron gutter, *e*, lined with loam, is fitted to the orifice.

d, hoops of hammered iron, 4¼ inches broad; one half of an inch thick for the bottom ones, and a quarter of an inch for the upper ones. The intermediate hoops decrease in thickness from below upwards between these limits.

e, cast iron gutter or spout, lined with loam, for running off the metal.

f f, cylindrical piece of cast iron, for increasing the height and draught of the furnace.

g, side openings for receiving the tuyères, of which there are six upon each side of the furnace. Each of them may be shut at pleasure, by means of a small cast iron plate *h*, made to slide horizontally in grooves sunk in the main plate, pierced with the holes *g g*.

k k, interior lining of the surface, made of sand, somewhat argillaceous, in the following way. After having laid at the bottom of the furnace a bed of sand a few inches thick, slightly sloped towards the orifice of discharge, there is set upright, in the axis of the cupola, a wooden cylinder of its whole height, and of a diameter a little less than that of the vacant space belonging to the top of the furnace. Sand is to be then rammed in so as to fill the whole of the furnace; after which the wooden cylinder is withdrawn, and the lining of sand is cut or shaved away, till it has received the proper form.

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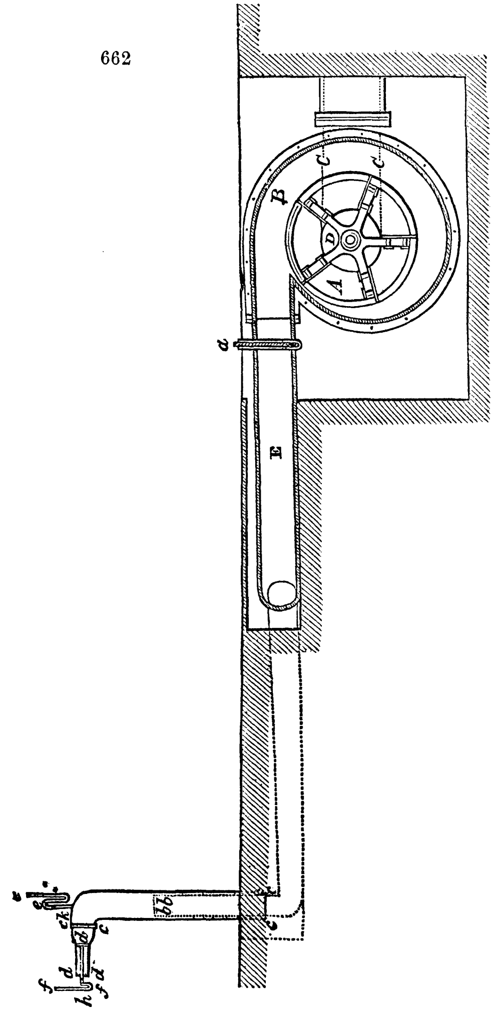

This lining lasts generally 5 or 6 weeks, when there are 6 meltings weekly.

i i, cast iron circular plate, through which the mouth of the furnace passes, for protecting the lining in *k* during the introduction of the charges.

N N, level of the floor of the foundry. The portion of it below the running out orifice consists of sand, so that it may be readily sunk when it is wished to receive the melted metal in ladles or pots of large dimensions.

The fan distributes the blast from the main pipe to three principal points, by three branch tubes of distribution. A register, consisting of a cast-iron plate sliding with friction in a frame, serves to intercept the blast at any moment, when it is not desirable to stop the moving power. A large main pipe of zinc or sheet iron is fitted to the orifice of the slide valve. It is square at the beginning, or only rounded at the angles but at a little distance it becomes cylindrical, and conducts the blast to the divaricating points. There, each of the branches turns up vertically, and terminates at *b b*, *fig.* 662, where it presents a circular orifice of $7\frac{1}{2}$ inches. Upon each of the upright pipes *b*, the one end of an elbow-tube of zinc *c c c c*, *fig.* 662, is adjusted rather loosely, and the other end receives a tuyère of wrought iron *d d*, through the intervention of a shifting hose or collar of leather *c c d*, hooped with iron wire to both the tube and the tuyère. The portion *c c c c* may be raised or lowered, by sliding upon the pipe *b*, in order to bring the nozzle of the tuyère *d d*, to the requisite point of the furnace. The portion *c c c c* may be made also of wrought iron. A power of 4 horses is adequate to drive this fan, for supplying blast to 3 furnaces.

The founders have observed the efflux of air was not the same when blown into the atmosphere, as it was when blown into the furnaces; the velocity of the fan, with the same impulsive power, being considerably increased in the latter case. They imagine that this circumstance arises from the blast being sucked in, so to speak, by the draught of the furnace, and that the fan then supplied a greater quantity of air.

The following experimental researches show the fallacy of this opinion. Two water syphons, *e e e*, *f f f*, made of glass tubes, one fifth of an inch in the bore, were inserted into the tuyère, containing water in the portions, *g g g*, *h h h*. The one of these *manometers* for measuring the pressure of the air was inserted at *k*, the other in the centre of the nozzle. The size of this glass tube was too small to obstruct in any sensible degree the outlet of the air. It was found that when the tuyères of the fan discharged into the open air, the expenditure by a nozzle of a constant diameter was proportional to the number of the revolutions of the vanes. It was further found, that when the speed of the vanes was constant, the expenditure by one or by two nozzles was proportional to the total area of these nozzles. The following formulæ give the volume of air furnished by the fan, when the number of turns and the area of the nozzles are known.

$$\text{Volume} = \frac{25{\cdot}32\ \mathrm{S\,n}}{1{\cdot}000{,}000} \qquad (1)$$

$$\text{Volume} = \frac{0{\cdot}8667\ \mathrm{S\,n}}{1{,}000{,}000} \qquad (2)$$

The volume is measured at 32° Fahr., under a pressure of 29·6 inches barom.

S = is the total area of the orifices of the tuyères in square inches.

n = the number of turns of the vanes in a minute.

After measuring the speed of the vanes blowing into the atmosphere, if we introduce the nozzle of discharge into the orifice of the furnace, we shall find that their speed immediately augments in a notable degree. We might, therefore, naturally suppose that the fan furnishes more air in the second case than in the first; but a little reflection will show that it is not so. In fact, the air which issues in a cold state from the tuyère encounters instantly in the furnace a very high temperature, which expands it, and contributes, along with the solid matters with which the furnace is filled, to diminish the facility of the discharge, and consequently to retard the efflux by the nozzles. The oxygen gas consumed is replaced by a like volume of carbonic acid gas, equally expansible by heat. Reason leads us to conclude that less air flows from the nozzles into the furnace than into the open atmosphere.

The increase in the velocity of the vanes takes place precisely in the same manner, when after having made the nozzles blow into the atmosphere, we substitute for these nozzles others of a smaller diameter, instead of directing the larger ones into the furnace. Hence we may conceive that the proximity of the charged furnace acts upon the blast like the contraction of the nozzles. When the moving power is uniform, and the velocity of the vanes remains the same, the quantity of air discharged must also be the same in the two cases.

Two tuyères, one 5 inches in diameter, the other $4\frac{1}{2}$, and which, consequently, presented a total area of $35\frac{1}{2}$ square inches, discharged air into one of the furnaces, from a fan whose vanes performed 654 turns in the minute. These two nozzles being briskly withdrawn from the furnace, and turned round to the free air, while a truncated pasteboard cone of $3\frac{1}{2}$ inches diameter was substituted for the nozzle of $4\frac{1}{2}$ inches, whereby the area of efflux was reduced to 29·3 square inches, the velocity of the vanes continued exactly the same. The inverse operation having been performed, that is to say, the two original nozzles having been smartly replaced in the furnace, to discover whether or not the moving power had changed in the interval of the experiment, they betrayed no perceptible alteration of speed. From the measures taken to count the speed, the error could not exceed 3 revolutions per minute, which is altogether unimportant upon the number 654.

It follows, therefore, that when the vanes of the fan have the velocity of 654 turns per minute, the expenditure by two nozzles, whose joint area is 35½ square inches, both blowing into a furnace, is to the expenditure which takes place, when the same nozzles blow into the air, as 35·5 is to 29·3; that is, a little more than four fifths.

If this be, as is probable, a general rule for areas and speeds considerably different from the above, to find the quantity of air blown into one or more furnaces by the fan, we should calculate the volume by one of the above formulæ (1) or (2), and take four fifths of the result as the true quantity.

The fan A C here represented is of the best eccentric form, as constructed by Messrs. Braithwaite and Ericsson. D is the circular orifice round the axis by which the air is admitted; and C C B is the eccentric channel through which the air is wafted towards the main discharge pipe E.

FOUNTAIN; a stream of water rising up through the superficial strata of the earth. See ARTESIAN WELLS.

FOXING is a term employed by brewers to characterize the souring of beer in the process of its fermentation or ripening.

FRANKFORT BLACK is made by calcining vine branches, and the other refuse lees of the vinegar vats in Germany. They must be previously washed.

FREEZING. (*Congelation*, Fr.; *Gefrierung*, Germ.) The three general forms, solid, liquid, and gaseous, under one or other of which all kinds of matter exist, seem to be immediately referable to the influence of heat; modifying, balancing, or subduing the attraction of cohesion. Every solid may be liquefied, and every liquid may be vaporized, by a certain infusion of caloric, whether this be regarded as a moving power or an elastic essence. The converse of this proposition is equally true; for many gases, till lately styled permanent, may be liquefied, nay, even solidified, by diminution of their temperature, either alone, or aided by a condensing force, to bring their particles within the sphere of aggregative attraction. When a solid is transformed into a liquid, and a liquid into a gas or vapor, a quantity more or less considerable of heat is absorbed, or becomes latent, to use the term of Dr. Black, the celebrated discoverer of this great law of nature. When the opposite transformation takes place, the heat absorbed is again emitted, or what was latent becomes sensible caloric. Upon the first principle, or the absorption of heat, are founded the various artificial methods of producing cold and congelation.

Tables exhibiting a collective view of all the Frigorific Mixtures contained in Mr. Walker's publication, 1808.

I.—Table consisting of Frigorific Mixtures, composed of ice, with chemical salts and acids.

Frigorific Mixtures with Ice.

MIXTURES.	Thermometer sinks.		Degree of cold produced.
Snow, or pounded ice - 2 parts Muriate of soda - - 1	From any temperature	to — 5°	*
Snow, or pounded ice - 5 parts Muriate of soda - - 2 Muriate of ammonia - - 1		to — 12°	*
Snow, or pounded ice - 24 parts Muriate of soda - - 10 Muriate of ammonia - 5 Nitrate of potash - - 5		to — 18°	*
Snow, or pounded ice - 12 parts Muriate of soda - - 5 Nitrate of ammonia - - 5		to — 25°	*
Snow - - - 3 parts Diluted sulphuric acid - 2	From + 32° to — 23°		55
Snow - - - 8 parts Muriatic acid - - 5	From + 32° to — 27°		59
Snow - - - 7 parts Diluted nitric acid - - 4	From + 32° to — 30°		62
Snow - - - 4 parts Muriate of lime - - 5	From + 32° to — 40°		72
Snow - - - 2 parts Cryst. muriate of lime - 3	From + 32° to — 50°		82
Snow - - - 3 parts Potash - - - 4	From + 32° to — 51°		83

N. B.—The reason for the omissions in the last column of the preceding table **is, the thermometer** sinking in these mixtures to the degree mentioned in the preceding **column, and** never lower, whatever may be the temperature of the materials at mixing.

II.—Table, consisting of Frigorific Mixtures, having the power of generating or creating cold, without the aid of ice, sufficient for all useful and philosophical purposes, in any part of the world at any season.

Frigorific Mixtures without Ice.

MIXTURES.	Thermometer sinks.	Degree of cold produced.
Muriate of ammonia - - 5 parts Nitrate of potash - - 5 Water - - - 16	From + 50° to + 10°	40°
Muriate of ammonia - 5 parts Nitrate of potash - - 5 Sulphate of soda - - 8 Water - - - 16	From + 50° to + 4°	46
Nitrate of ammonia - - 1 part Water - - - 1	From + 50° to + 4°	46
Nitrate of ammonia - - 1 part Carbonate of soda - - 1 Water - - - 1	From + 50° to — 7°	57
Sulphate of soda - - 3 parts Diluted nitric acid - - 2	From + 50° to — 3°	53
Sulphate of soda - - 6 parts Muriate of ammonia - 4 Nitrate of potash - - 2 Diluted nitric acid - - 4	From + 50° to — 10°	60
Sulphate of soda - - 6 parts Nitrate of ammonia - - 5 Diluted nitric acid - - 4	From + 50° to — 14°	64
Phosphate of soda - - 9 parts Diluted nitric acid - - 4	From + 50° to — 12°	62
Phosphate of soda - - 9 parts Nitrate of ammonia - - 6 Diluted nitric acid - - 4	From + 50° to — 21°	71
Sulphate of soda - - 8 parts Muriatic acid - - - 5	From + 50° to 0°	50
Sulphate of soda - - 5 parts Diluted sulphuric acid - 4	From + 50 to + 3°	47

N. B.—If the materials are mixed at a warmer temperature than that expressed in the table, the effect will be proportionably greater; thus, if the most powerful of these mixtures be made when the air is + 85°, it will sink the thermometer to + 2°.

III.—Table consisting of Frigorific Mixtures selected from the foregoing Tables, **and** combined so as to increase or extend cold to the extremest degrees.

Combinations of Frigorific Mixtures.

MIXTURES.	Thermometer sinks.	Degree of cold produced.
Phosphate of soda - - 5 parts Nitrate of ammonia - - 3 Diluted nitric acid - - 4	From 0° to — 34°	**34°**
Phosphate of soda - - 3 parts Nitrate of ammonia - - 2 Diluted mixed acids - - 4	From — 34° to — 50°	**16**
Snow - - - 3 parts Diluted nitric acid - - 2	From 0° to — 46°	**46**

TABLE III.—*continued.*

MIXTURES	Thermometer sinks.	Deg. of cold produced.
Snow - - - - - 8 parts Diluted sulphuric acid - 3 Diluted nitric acid - - 3	From — 10° to — 56°	46
Snow - - - - - 1 part Diluted sulphuric acid. - - 1	From — 20° to — 60°	40
Snow - - - - - 3 parts Muriate of lime - - - 4	From + 20° to — 48°	68
Snow - - - - - 3 parts Muriate of lime - - - 4	From + 10° to — 54°	64
Snow - - - - - 2 parts Muriate of lime - - - 3	From — 15° to — 68°	53
Snow - - - - - 1 part Cryst. muriate of lime - - 2	From 0° to — 66°	66
Snow - - - - - 1 part Cryst. muriate of lime - - 3	From — 40° to — 73°	33
Snow - - - - - 8 parts Diluted sulphuric acid - - 10	From — 68° to — 91°	23

N. B.—The materials in the first column are to be cooled, previously to mixing, to the temperature required, by mixtures taken from either of the preceding tables.

Water absorbs 1000 degrees of heat in becoming vapor; whence, if placed in a saucer within an exhausted receiver, over a basin containing strong sulphuric acid, it will freeze by the rapid absorption of its heat into the vapor so copiously formed under these circumstances.

But the most powerful means of artificial refrigeration is afforded by the evaporation of liquefied carbonic acid gas; for the frozen carbonic acid thus obtained has probably a temperature 100° under zero; so that when a piece of it is laid upon quicksilver, it instantly congeals this metal. The more copious discussion of this subject belongs to chemical science.

FRENCH BERRIES; Berries of Avignon.

FRICTION, counteraction of; see LUBRICATION.

FRIT; see ENAMEL and GLASS.

FUEL (*Combustible*, Fr.; *Brennstoff*, Germ.)

Such combustibles as are used for fires or furnaces are called fuel, as wood, turf, pit-coal. These differ in their nature and in their power of giving heat.

I. Wood, which is divided into hard and soft. To the former belong the oak, the beech, the alder, the birch, and the elm; to the latter, the fir, the pine of different sorts, the larch, the linden, the willow, and the poplar.

Under like dryness and weight different woods are found to afford equal degrees of heat in combustion. Moisture diminishes the heating power in three ways; by diminishing the relative weight of the ligneous matter, by wasting heat in its evaporation, and by causing slow and imperfect combustion. If a piece of wood contain, for example, 25 per cent. of water, then it contains only 75 per cent. of fuel, and the evaporation of that water will require $\frac{1}{28}$ part of the weight of the wood. Hence the damp wood is of less value in combustion by $\frac{8}{28}$ or $\frac{2}{7}$ than the dry. The quantity of moisture in newly felled wood amounts to from 20 to 50 per cent.; birch contains 30, oak 35, beech and pine 39, alder 41, fir 45. According to their different natures, woods which have been felled and cleft for 12 months contain still from 20 to 25 per cent. of water. There is never less than 10 per cent. present, even when it has been kept long in a dry place, and though it be dried in a strong heat, it will afterwards absorb 10 or 12 per cent. of water. If it be too strongly kiln dried, its heating powers are impaired by the commencement of carbonization, as if some of its hydrogen were destroyed. It may be assumed as a mean of many experimental results, that 1 pound of artificially dried wood will heat 35 pounds of water from the freezing to the boiling point; and that a pound of such wood as contains from 20 to 25 per cent. of water will heat 26 pounds of ice-cold water to the same degree. It is better to buy wood by measure than by weight, as the bulk is very little increased by moisture. The value of different woods for fuel is inversely as their moisture, and this may easily be ascertained by taking their shavings, drying them in a heat of 140° F., and seeing how much weight they lose.

From every combustible the heat is diffused either by radiation or by direct communication to bodies in contact with the flame. In a wood fire the quantity of radiating heat is to that diffused by the air as 1 to 3; or it is one fourth of the whole heating power

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II. *Charcoal.* The different charcoals afford, under equal weights, equal quantities of heat. We may reckon, upon an average, that a pound of dry charcoal is capable of heating 73 pounds of water from the freezing to the boiling point; but when it has been for some time exposed to the air, it contains at least 10 per cent. of water, which is partially decomposed in the combustion into carbureted hydrogen, which causes flame, whereas pure dry charcoal emits none.

A cubic foot of charcoal from soft wood, weighs, upon an average, from 8 to 9 pounds, and from hard wood 12 to 13 pounds; and hence the latter are best adapted to maintain a high heat in a small compass. The radiating heat from charcoal fires constitutes one third of the whole emitted.

III. *Pitcoal.* The varieties of this coal are almost indefinite, and give out very various quantities of heat in their combustion. The carbon is the heat-giving constituent, and it amounts, in different coals, to from 75 to 95 per cent. One pound of good pitcoal will, upon an average, heat 60 pounds of water from the freezing to the boiling point. Small coal gives out three fourths of the heat of the larger lumps. The radiating heat emitted by burning pitcoal is greater than that by charcoal.

IV. *The coke of pitcoal.*—The heating power of good coke is to that of pitcoal as 75 to 69. One pound of the former will heat 65 pounds of water from 32° to 212°; so that its power is equal to nine tenths of that of wood charcoal.

V. *Turf or peat.*—One pound of this fuel will heat from 25 to 30 pounds of water from freezing to boiling. Its value depends upon its compactness and freedom from earthy particles; and its radiating power is to the whole heat it emits in burning as 1 to 3.

VI. *Carbureted hydrogen or coal gas.*—One pound of this gas, equal to about 24 cubic feet, disengages, in burning, as much heat as will raise 76 pounds of water from the freezing to the boiling temperature.

In the following table the fourth column contains the weight of atmospherical air, whose oxygen is required for the complete combustion of a pound of each particular substance.

Species of combustible.	Pounds of water which a pound can heat from 0° to 212°.	Pounds of boiling water evaporated by 1 pound.	Weight of atmospheric air at 32°, to burn 1 pound.
Perfectly dry wood	35·00	6·36	5·96
Wood in its ordinary state	26·00	4·72	4·47
Wood charcoal	73·00	13·27	11·46
Pitcoal	60·00	10·90	9·26
Coke	65·00	11·81	11·46
Turf	30·00	5·45	4·60
Turf charcoal	64·00	11·63	9·86
Carbureted hydrogen gas	76·00	13·81	14·58
Oil Wax Tallow	78·00	14·18	15·00
Alcohol of the shops	52·60	9·56	11·60

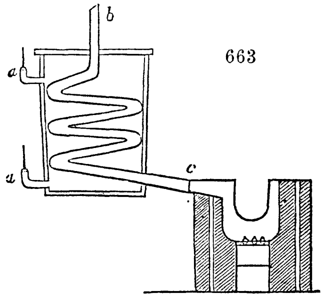
The quantity of air stated in the fourth column is the smallest possible required to burn the combustible, and is greatly less than would be necessary in practice, where much of the air never comes into contact with the burning body, and where it consequently never has its whole oxygen consumed. The heating power stated in the second column is also the maximum effect, and can seldom be realized with ordinary boilers. The draught of air usually carries off at least $\frac{1}{7}$ of the heat, and more if its temperature be very high when it leaves the vessel. In this case it may amount to one half of the whole heat or more; without reckoning the loss by radiation and conduction, which, however, may be rendered very small by enclosing the fire and flues within proper non-conducting and non-radiating materials.

It appears that, in practice, the quantity of heat which may be obtained from any combustible in a properly mounted apparatus must vary with the nature of the object to be heated. In heating chambers by stoves, and water boilers by furnaces, the effluent heat in the chimney which constitutes the principal waste may be reduced to a very moderate quantity, in comparison of that which escapes from the best constructed reverberatory hearth. In heating the boilers of steam engines, one pound of coal is reckoned adequate to convert 7½ pounds of boiling water into vapor; or to heat 41¼ pounds of water from the freezing to the boiling point. One pound of fir of the usual dryness will evaporate 4 pounds of water, or heat 22 pounds to the boiling temperature; which is about two thirds of the maximum effect of this combustible. According to Watt's experiments upon the great scale, one pound of coal can boil off, with the best built boiler, 9 pounds of water; the deficiency from the maximum effect being here $\frac{10}{57}$, or nearly one sixth.

In many cases, the hot air which passes into the flues or chimneys may be beneficially applied to the heating, drying, or roasting of objects; but care ought to be taken that the draught of the fire be not thereby impaired, and an imperfect combustion of the fuel produced. For at a low smothering temperature both carbonic oxyde and carbureted hydrogen may be generated from coal, without the production of much heat in the fire-place.

To determine exactly the quantity of heat disengaged by any combustible in the act of burning, three different systems of apparatus have been employed: 1. the calorimeter of Lavoisier and Laplace, in which the substance is burned in the centre of a vessel, whose walls are lined with ice; and the amount of ice melted, measures the heat evolved; 2. the calorimeter of Watt and Rumford, in which the degree of heat communicated to a given body of water affords the measure of temperature; and 3. by the quantity of water evaporated by different kinds of fuel in similar circumstances.

If our object be to ascertain the relative heating powers of different kinds of fuel, we need not care so much about the total waste of heat in the experiments, provided it be the same in all; and therefore they should be burned in the same furnace, and in the same way. But the more economically the heat is applied, the greater certainty will there be in the results. The apparatus *fig.* 663, is simple and well adapted to make such comparative trials of fuel. The little furnace is covered at top, and transmits its burned air by *c*, through a spiral tube immersed in a cistern of water, having a thermometer inserted near its top, and another near its bottom, into little side orifices *a a*, while the effluent air escapes from the upright end of the tube *b*. Here also a thermometer bulb may be placed. The average indication of the two thermometers gives the mean temperature of the water. As the water evaporates from the cistern, it is supplied from a vessel placed alongside of it. The experiment should be begun when the furnace has acquired an equability of temperature. A throttle valve at *c* serves to regulate the draught, and to equalize it in the different experiments by means of the temperature of the effluent air. When the water has been heated the given number of degrees, which should be the same in the different experiments, the fire may be extinguished, the remaining fuel weighed, and compared with the original quantity. Care should be taken to make the combustion as vivid and free from smoke as possible.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On the measurement of heat, and the qualities of different kinds of coal, I made an elaborate series of experiments, a few years ago, of which the following is an outline.

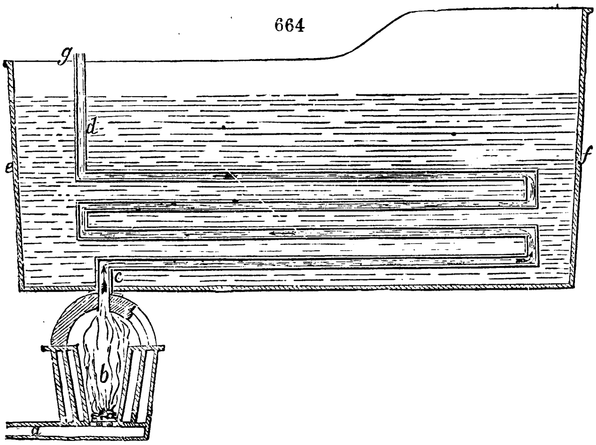
The first and most celebrated, though probably not the most accurate apparatus for measuring the quantity of heat transferable from a hotter to a colder body, was the calorimeter of Lavoisier and Laplace. It consisted of three concentric cylinders of tin plate, placed at certain distances asunder; the two outer interstitial spaces being filled with ice, while the innermost cylinder received the hot body, the subject of experiment. The quantity of water discharged from the middle space by the melting of the ice in it, served to measure the quantity of heat given out by the body in the central cylinder. A simpler and better instrument on this principle would be a hollow cylinder of ice of proper thickness, into whose interior the hot body would be introduced, and which would indicate by the quantity of water found melted within it the quantity of heat absorbed by the ice. In this case, the errors occasioned by the retention of water among the fragments of ice packed into the cylindric cell of the tin calorimeter, would be avoided. One pound of water at 172° F., introduced into the hollow cylinder above described, will melt exactly one pound of ice; and one pound of oil heated to 172° will melt half a pound.

The method of refrigeration, contrived at first by Meyer, has been in modern times brought to great perfection by Dulong and Petit. It rests on the principle, that two surfaces of like size, and of equal radiating force, lose in like times the same quantity of heat when they are at the same temperature. Suppose for example, that a vessel of polished silver, of small size, and very thin in the metal, is successively filled with different pulverized substances, and that it is allowed to cool from the same elevation of temperature; the quantities of heat lost in the first instant of cooling will be always equal to each other; and if for one of the substances, the velocity of cooling is double of that for another, we may conclude that its capacity for heat is one half, when its weight is the same; since by losing the same quantity of heat, it sinks in temperature double the number of degrees.

The method of mixtures.—In this method, two bodies are always employed; a hot body which becomes cool, and a cold body, which becomes hot, in such manner that all the caloric which goes out of the former is expended in heating the latter. Suppose for example, that we pour a pound of quicksilver at 212° F., into a pound of water at 32°; the quicksilver will cool and the water will heat, till the mixture by stirring acquires a common temperature. If this temperature was 122°, the water and mercury would have equal capacities, since the same quantity of heat would produce in an equal mass of these two substances equal changes of temperature, viz., an elevation of 90° in the water and a depression of 90° in the mercury. But in reality, the mixture is found to have a temperature of only 37½°, showing that while the mercury loses 174½° the water gains only 5½°; two numbers in the ratio of about 32 to 1; whence it is concluded, that the capacity of mercury is $\frac{1}{32}$ of that of water. Corrections must be made for the influence of the vessel and for the heat dissipated during the time of the experiment.

The following calorimeter, founded upon the same principle as that of Count Rumford, but with certain improvements, may be considered as an equally correct instrument for measuring heat, with any of the preceding, but one of much more general application, since it can determine the quantity of heat disengaged in combustion, as well as the latent heat of steam and other vapors.

664



(Scale about ½ inch to the foot.)

It consists of a large copper bath, *e*, *f* (*fig.* 664), capable of holding 100 gallons of water. It is traversed four times, backward and forward, in four different levels, by a zig-zag horizontal flue, or flat pipe *d*, *c*, nine inches broad and one deep, ending below in a round pipe at *c*, which passes through the bottom of the copper bath *e*, *f*, and receives there into it the top of a small black lead furnace *b*. The innermost crucible contains the fuel. It is surrounded at the distance of one inch by a second crucible, which is enclosed at the same time by the sides of the outermost furnace; the strata of stagnant air between the crucibles serving to prevent the heat from being dissipated into the atmosphere round the body of the furnace. A pipe *a*, from a pair of cylinder double bellows, enters the ash-pit of the furnace at one side, and supplies a steady but gentle blast, to carry on the combustion, kindled at first by half an ounce of red-hot charcoal. So completely is the heat which is disengaged by the burning fuel absorbed by the water in the bath, that the air discharged at the top orifice *g*, has usually the same temperature as the atmosphere.

The vessel is made of copper, weighing two pounds per square foot; it is 5½ feet long, 1½ wide, 2 deep, with a bottom 5½ feet long, and $1\frac{8}{4}$ broad, upon an average. Including the zig-zag tin plate flue, and a rim of wrought iron, it weighs altogether 85 pounds. Since the specific heat of copper is to that of water as 94 to 1,000; the specific heat of the vessel is equal to that of 8 pounds of water, for which, therefore, the exact correction is made by leaving 8 pounds of water out of the 600, or 1,000 pounds used in each experiment.

In the experiments made with former calorimeters of this kind, the combustion was maintained by the current or draft of a chimney, open at bottom, which carried off at the top orifice of the flue a variable quantity of heat, very difficult to estimate.

When the object is to determine the latent heat of steam and other vapors, they may be introduced through a tube into the orifice *g*, the latent heat being deduced from the elevation of temperature in the water of the bath, and the volume of vapor expended from the quantity of liquid discharged into a measure glass from the bottom outlet *c* In this case, the furnace is of course removed.

The heating power of the fuel is measured by the number of degrees of temperature which the combustion of one pound of it, raises 600 or 1,000 pounds of water in the bath, the copper substance of the vessel being taken into account. One pound of dry wood charcoal by its combustion causes 6,000 pounds of water to become 20° hotter. For the sake of brevity, we shall call this calorific energy 12,000 unities. In like circumstances, one pound of Llangennoek coal will yield by combustion 11,500 unities of caloric. One pound of charcoal after exposure to the air gives out in burning only 10,500 unities; but when previously deprived of the moisture which it so greedily imbibes from the atmosphere, it affords the above quantity. One pound of Lambton's Wall's-end coals, affords 8,500 unities; and one of anthracite 11,000.

It must be borne in mind that a coal which gives off much unburnt carburetted hydrogen gas, does not afford so much heat, since in the production of the gas a great deal of heat is carried off in the latent state. I have no doubt, that by this distillatory process, from one third to one fourth of the total calorific effect of many coals is dissipated in the air. But by means of such a furnace as the patent Argand invention of Mr. C. W. Williams, the whole heat produceable by the hydrogen as well as the carbon is obtained; and it should be borne in mind that a pound of hydrogen in burning generates as much heat as three pounds of carbon.

Mr. Berthier proposes to determine the proportion of carbon in coals and other kinds of fuel, by igniting in a crucible a mixture of the carbonaceous matter with litharge, both finely comminuted, and observing the quantity of lead which is reduced. For every 34 parts of lead, he estimates 1 part of carbon, apparently on the principle, that when carbon is ignited in contact with abundance of litharge, it is converted into carbonic acid. Each atom of the carbon is therefore supposed to seize two atoms of oxygen, for which it must decompose two atoms of litharge, and revive two atoms of lead. Calling the atom of carbon 6, and that of lead 104, we shall have the following ratio :—$6 : \overline{104 \times 2} :: 1 : 34.66$, being Berthier's proportion, very nearly.

On subjecting this theory to the touchstone of experiment, I have found it to be entirely fallacious. Having mixed very intimately 10 grains of recently calcined charcoal with 1,000 grains of litharge, both in fine powder, I placed the mixture in a crucible which was so carefully covered, as to be protected from all fuliginous fumes, and exposed it to distinct ignition. No less than 603 grains of lead were obtained; whereas by Berthier's rule, only 340 or 346.6 were possible. On igniting a mixture of 10 grains of pulverized anthracite from Merthyr Tydfil, with 500 grains of pure litharge (previously fused and pulverized), I obtained 380 grains of metallic lead. In a second similar experiment with the same anthracite and litharge, I obtained 450 grains of lead; and in a third only 350 grains. It is therefore obvious that this method of Berthier is altogether nugatory for ascertaining the quantity of carbon in coals, and is worse than useless for judging of the calorific qualities of different kinds of fuel.

In my researches upon coals, I have also made it one of my principal objects to determine the quantity of sulphur which they may contain; a point which has been hitherto very little investigated in this country at least, but which is of great consequence, not only in reference to their domestic combustion, but to their employment by manufacturers of iron and gas. That good iron can not be produced with a sulphureous coal, however well coked, has been proved in France by a very costly experience. The presence of a notable proportion of sulphur in a gas coal is most injurious to the gaseous products, because so much sulphuretted hydrogen is generated as to require an operose process of washing or purification, which improverishes the gas, and impairs its illuminating powers by the abstraction of its olefiant gas, or bicarburetted hydrogen. In proof of this proposition, I have only to state the fact, that I found in a specimen of coal gas as delivered from the retorts of one of the metropolitan companies, no less than 18 per cent. of olefiant gas, while in the same gas, after being passed through the purifiers, there remained only 11 per cent. of that richly-illuminating gas. By using a gas-coal, nearly free from sulphur, such as No. 4, in the subjoined list, I think it probable that 10 per cent. of more light may be realized than with the common more sulphureous coal. This is an important circumstance which the directors of gas-works have hitherto neglected to investigate with analytical precision, though it is one upon which their success and profits mainly depend.

How little attention indeed has been bestowed upon the sulphureous impregnation of pit-coal may be inferred from the fact that one of our professional chemists of note, in a public report, upon a great commercial enterprise, stated that a certain coal analyzed by him was free from sulphur, which coal I found by infallible chemical evidence to contain no less than 7 per cent. of sulphur, being about the double of what is contained in English coals of average quality. The proportion of sulphur may in general be inferred from the appearance and quantity of the ashes. If these be of a red or ochrey color, and amount to above 10 per cent., we may be sure that the coal is eminently sulphureous. The coal above referred to afforded from 15 to 16 per cent. of ferruginous ashes. I believe that sulphur exists in coal generally, though not always in the state of pyrites, either in manifest particles, or invisibly disseminated through their substance.

The readiest method of determining rigidly the quantity of sulphur in any compound, is to mix a given weight of it with a proper weight of carbonate of potassa, nitre, and common salt, each chemically pure, and to ignite the mixture in a platinum crucible. A whitish mass is obtained, in which all the sulphur has been converted into sulphate of potassa. By determining with nitrate of baryta the amount of sulphuric acid produced, that of the sulphur becomes known. By means of this process applied to different samples of coals, I obtained the following results:—

Gas Coals.	Sulphur in 100 parts.	Gas Coals.	Sulphur in 100 parts.
No. 1	3·00	No. 5	2·50
2	3·90	6	5·20
3	2·42	7	3·40
4	3·80	8	3·50

Coals for puddling cast iron, to be converted into steel,		Sulphur in 100 parts
No. 1, hard foliated or splent coal, specific gravity	1·258	0·80
2, ditto	1·290	0·96
3, ditto	1·273	3·10
4, cubical and rather soft	1·267	0·80

The last coal being rich in bitumen, would prove an excellent one for the production of a pure coal gas. See PITCOAL.

FUEL, ECONOMY OF. In the report of the Transactions of the Institution of Civil Engineers for February, 1838, the results of exact comparisons between the performance of different steam-engines exhibit this economy in a remarkable manner. It is there shown that a condensing engine of the most perfect construction, and in perfect condition, of the common low pressure crank-kind, not working expansively, performs a duty of not more than 20 or 21 millions of lbs. raised one foot high, by 90 or 94 lbs. of coal; or ten lbs. of coal per horse power per head.

The following table exhibits the relative value of different engines in lbs. of coal per horse power per hour:—

Cornish Pumping Engine	1·57
Bolton and Watt's Single Engine	4·82
Cornish Double Engine	3·25
Bolton and Watt's Double Engine	10·5

The greatest duty performed by the measured bushel of 84 lbs. was 86½ millions of lbs. There was raised by the Huel Towan engine in Cornwall 1,085 tons (of water) one foot high for one farthing. Hence the weight of a man (1½ cwt.) would be raised ten miles for one penny!

In order to raise steam with economy, the surface of water in the boiler, exposed to the fire, ought not to be less thon 10 square feet per horse power; but the usual allowance in Lancashire is only 7½; and by Messrs. Boulton and Watt, 5 square feet.

The values of the mean of the Cornish, Warwick, London, Lancashire, and locomotive experiments, as reported by Mr. Josiah Parkes, were respectively 21, 18, 13½, and 10 cubic feet of water evaporated by 112 lbs. of coals, from water heated to 212° F.

FUEL, GRANT'S PATENT. This fuel is composed of coal-dust and coal-tar pitch; these materials are mixed together, under the influence of heat, in the following proportions:—20 lbs. of pitch to 1 cwt. of coal-dust, by appropriate machinery consisting of crushing-rollers for breaking the coal in the first instance sufficiently small, so that it may pass through a screen the meshes of which do not exceed a quarter of an inch asunder; 2dly, of mixing-pans or cylinders, heated to the temperature of 220°, either by steam or heated air; and, 3dly, of moulding machines, by which the fuel is compressed, under a pressure equal to five tons, into the size of a common brick; the fuel bricks are then whitewashed, which prevents their sticking together, either in the coal bunkers or in hot climates. The advantages of Grant's fuel over even the best coal may be stated to consist, first, in its superior efficacy in generating steam, which may be thus stated—200 tons of this fuel will perform the same work as 300 tons of coal, such as are generally used; secondly, it occupies less space; that is to say, 500 tons of it may be stowed in an area which will contain only 400 tons of coal; thirdly, it is used with much greater ease by the stokers or firemen than coal, and it creates little or no dirt or dust, considerations of some importance when the delicate machinery of a steam-engine is considered; fourthly, it produces a very small proportion of clinkers, and thus it is far less liable to choke and destroy the furnace bars and boilers than coal; fifthly, the ignition is so complete that comparatively little smoke, and only a small quantity of ashes, are produced by it; sixthly, from the mixture of the patent fuel, and the manner of its manufacture, it is not liable to enter into spontaneous ignition.

Fuel chiefly Pit Coal. "Considering the vast importance of the subject, it is somewhat remarkable that no exact mode of determining the true value of coal as a fuel has ever yet been invented. Of the methods hitherto in use there is not one which deserves the title even of an approximation to the truth. The plan of Berthier, as has been well shown by Dr. Ure, is beyond all things fallacious, though this very plan is that most relied on by the experimenters connected with the late Admiralty investigation respecting the coals best suited for the steam navy. It needs, however, but a moment's reflection to see that this process of Berthier can never afford a correct result, for the agent employed is litharge, a substance not acted on at all until exposed to heat more than sufficient for the expulsion of the volatile constituents of coal, and moreover a substance capable of being reduced at high temperatures by the carbonic oxide gas of the fire employed to effect the assay. Here then are two enormous sources of error; for in the first place the hydrogenous constituents of the coal can never be estimated at all, and in the second the litharge by mere exposure in a crucible to the action of the fire will give metallic lead exactly the same as if coal existed in it, so that not the least dependence in the world can be placed in this method. Numerous and carefully conducted experiments have fully confirmed the original observations of Dr. Ure upon this matter, and, in fact, the results from four crucibles, each charged with the same quantities of coal and litharge, taken from the same massive powder, and placed side by side in the same furnace, and treated in all respects exactly alike, have shown a discordance equal to the numbers 117, 142, 156, and 163. To think of attaching any value to any of these, or to the average which they present, is to lose sight of the most important province of chemistry in its relation to the arts.

"Another, and certainly a preferable method, is to consume a given amount of each coal in a calorimeter, so as to measure the total heat disengaged during combustion. But here, again, we meet with difficulties more than enough to destroy all confidence in the results. Thus it is not possible thoroughly to consume the whole of the fuel in this way. Of the volatile constituents of the coal, a portion always passes off unburnt in the shape of carburetted hydrogen, tar, and soot, whilst of the carbon or fixed constituents, part is constantly lost in the form of carbonic oxide gas. So that no real estimate of the calorific value of a coal can be arrived at in this way, and even comparative experiments are worthless from the great inequalities which prevail in the ratio of the volatile and fixed ingredients in different coals, as well as from the changes induced by accidental variations of draught through the body of the fuel. Of course the same objections apply to what are called practical experiments, conducted with any one particular form of furnace or setting of a boiler. The form of furnace, as is well known, requires to be adapted to the fuel, and not the fuel to the furnace: nevertheless, in the Admiralty experiments already alluded to, the only form of furnace and boiler employed was that called the Cornish setting, though this particular form was expressly invented for, and will, as is notorious, do justice to no other kind of coal than anthracite. Hence the parliamentary reports which chronicles the results of the Procrustean theorem, though yet almost wet from the press, is even now rapidly on its road to the butter-shop, there to expiate, by the humblest of services, its previous utter inutility to the public. To know the precise amount of heat evolved from coals during their combustion, must, as has been before remarked, be a subject of the greatest possible interest, for until the total calorific power be taken into account, it is impossible for us to appreciate the loss which ensues under the existing modes of consuming fuel. At present it seems generally agreed, that ordinary Newcastle coal will evaporate about 8 times its weight of water, or in other words, that a ton of such coal will boil off or convert into steam 17,920 lbs. of water. If, however, we proceed to a practical analysis of this very coal, by examining the heating power of its gaseous and fixed constituents, after these have been separated from each other, we shall find that the above is very far short of the most moderate estimate that can be formed of the heat which must be disengaged; and whether the difference be lost by imperfect combustion, or by the action of the chimney, or in what other way, remains still to be decided by those who seek to improve our present modes of consuming fuel. The following table represents the actual heat evolved, and of water evaporated, by the different constituents of one ton of the Newcastle coal called Pelton; and it must be remembered, that so far as chemical research has yet gone, the heat evolved from a combustible is in proportion to the amount of oxygen consumed, and has no connection with the particular mechanical state of the combustible. For instance, there is no reason to suppose that gaseous carbon, if we possessed such a substance, would evolve either more or less heat than its equivalent weight of solid carbon, in combining with the same quantity of oxygen gas. Whether, therefore, we regard the constituents of coal as existing in the solid or gaseous form, does not, according to our present knowledge, alter the proportion of heat which these constituents would give out during their perfect oxidation. Now one ton of Pelton coal affords

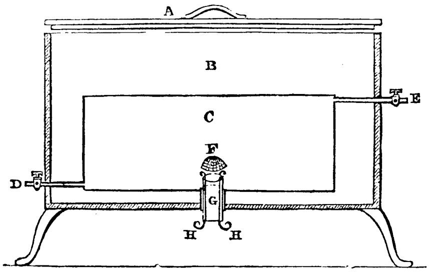
10,000 cubic feet of gaseous matters,
10 gallons or about 125 lbs. of tar,
and 41 bushels or 1680 lbs. of coke;

and, by experiment, it has been found that the above gas before purification will boil off for every cubic foot consumed 10½ ounces of water; that 3 gallons of tar are equal to about one bushel of coke; and that the coke will boil off 10 times its weight of water Hence we have the total amount of water evaporated as under:

10,000 cubic feet of gas at 10½ ounces per foot = 6537 lbs.
10 gallons of tar equal to 3·33 bushels of coke = 1365 lbs.
1680 lbs. of coke at 10 lbs. per lb. - - = 16800 lbs.

Total 24702

or upwards of 11 lbs. of water for every lb. of coal. It happens, however, that even this estimate is too low, and that actual experiments on this very coal shows its true heating power to be not less than 12. To elucidate this it becomes necessary, however, to enter into an explanation of the means employed for ascertaining the precise amount of heat evolved by any combustible during its complete oxidation, and which is perhaps the only approach to accuracy that has yet been proposed with this view. A copper vessel, shaped like a parallelogram, and having in its ends two small openings provided with stop cocks, has also in its lower surface a large opening of two inches in diameter, terminating in a tube or neck of about two inches in length and fitted with an earthenware plug or stopper. This parallelogram is enclosed in another and larger one, capable of holding in addition 20 lbs. of water. The smaller vessel should have an internal capacity of about half a cubic foot, or 800 cubic inches, and the different openings must pass out of and through the larger vessel. The earthenware stopper is to be provided with two small openings, in which pass two insulated copper wires, and on the top of the stopper is a cavity capable of holding 50 grains of coal in coarse powder, through which a fine platinum wire passes connected with the terminal ends of the two copper wires, and over the whole a cage of stout platinum wire is placed so as to prevent the coal from being thrown out during the experiment, and also to insure the complete combustion of all the volatile and fuliginous matter. To use this apparatus, 50 grains of the coal in question are placed in the cavity of the stopper, and the necessary connections being made by means of a fine platinum wire, the cage is applied, and the whole inserted in the neck or opening left for it, and which it hermetically closes: as soon as this is completed, a current of oxygen gas is made to traverse the smaller vessel by means of the stop-cocks in the sides, and this is continued until the atmospheric air being almost wholly expelled, the vessel remains full of oxygen gas; when this is the case water must be poured into the larger vessel, and a piece of ice introduced into it until the temperature has fallen about 5° below that of the apartment, when the ice must be withdrawn, and the coal lighted by means of a small galvanic battery, the poles of which need be applied but for a moment to the copper wires which pass through the earthenware stopper. Ignition instantly ensues, and is finished in two or three seconds, when the heat of the water in the larger vessel must be ascertained by a delicate thermometer, after proper agitation. It is of course necessary to take the usual precautions followed in experiments of this kind, and to surround the whole of the larger vessel by non-conductors of caloric, having carefully determined beforehand the absorption of heat due to the apparatus, so that this may be added to that of the water; the water itself should either be actually weighed or measured with great accuracy at a mean temperature, and the ice must also be weighed before and after immersion. The accompanying sketch in section will perhaps facilitate the comprehension of this instrument.



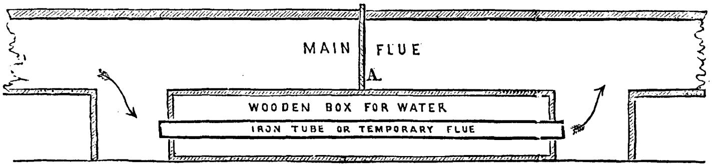
"A, cover made of wood; B, larger vessel of copper; C, smaller vessel of copper; D, entrance for oxygen gas; E, exit for atmospheric air; F, platinum cage; G, earthenware stopper with cavity in top; H H, copper wires for conveying electricity, between the upper extremities of which a fine platinum wire is loosely stretched which passes through the mass of powdered coal.

The results hitherto obtained by this apparatus are not very extensive, but nevertheless they embrace substantially many of the best established coals, and as might *à priori* be imagined, they moreover demonstrate in an undeniable manner the superiority of bituminous over anthracitic coals and coke,—a position directly the reverse of the absurd assumptions and foregone conclusions contained in the parliamentary report of Sir H. de la Beche and Dr. Playfair. The following is a tabular view of these results, with a column showing the evaporative power of each, deduced by assuming 980 as the latent heat of steam.

	Unities of Caloric.	Lbs. of Water capable of being evaporated by 1 lb. of Coal.
Newcastle:		
Pelton - - - - - - - - -	14800	15·1 lbs
Garesfield (Bates) - - - - - -	15200	15·5 —
Hastings Hartley - - - - - -	16175	16·5 —
West Hartley - - - - - - -	16280	16·6 —
Bates Hartley - - - - - - -	15985	16·3 —
Newcastle Hartley - - - - - -	16330	16·6 —
Heaton - - - - - - - - -	15075	15·6 —
Gosford - - - - - - - - -	15000	15·3 —
Killingworth - - - - - - -	14875	15·1 —
Durham:		
Hetton - - - - - - - - -	15660	16·0 —
Lambton - - - - - -	15450	15·7 —
Rainton - - - - - - - - -	14995	15·3 —
Yorkshire:		
Woodthorpe - - - - - - -	13780	14·0 —
Mortemly - - - - - - -	14010	14·3 —
North Wales:		
Brymbo - - - - - - - - -	13875	14·1 —
Ruabon - - - - - - - - -	14200	14·5 —
South Wales:		
Anthracite No. 1. - - - - - -	13090	13·3 —
Anthracite No. 2. - - - - - -	12875	13·1 —
Neath (Bituminous) - - - - -	13845	14·0 —
Ireland:		
Anthracite - - - - - - -	12990	13·2 —
Wigan:		
Cannel Ince Hall - - - - - -	14340	14·6 —
Scotch:		
Lesmahago Cannel - - - - - - .	12285	12·5 —
Newcastle:		
Ramsey's Cannel - - - - -	14420	14·7 —

Comparing these results with the actual working of most of the above bituminous coals, it appears that very nearly one half of all the heat evolved is lost in practice, and either passes off in the shape of unconsumed fuel, or is wasted in the chimney. With a view to ascertain how much of the loss is due to this latter circumstance, Mr. F. J. Evans, the eminent engineer of the Westminster station of the Chartered Gas Company, made some time ago an experiment bearing upon this subject, and in which the loss of heat is necessarily very high, from the fact that the substance heated by the furnace was almost white hot, whereas in a steam boiler the temperature never exceeds 300° of Fahr. Mr. Evans's experiment, which shows no trifling amount of ingenuity, nevertheless demonstrates that not more than 3 per cent. of the fuel passes off by the heat of the chimney; consequently at least 15 times this amount must be lost by imperfect combustion, and fly away in the shape of carburetted hydrogen, tarry vapour, or carbonic oxide; thus leaving a wide field for improvement in burning and applying fuel. We give the following in Mr. Evans's own words.

"'Experiments on waste heat: to determine the quantity of heat going away to the chimney from a setting of 8 retorts. A deal box was constructed of the following dimensions; length 5 feet 6 inches, width 11 inches, and depth 7 inches, and quite water-tight. Within this box, and running through it, was placed an iron tube of the following dimensions; length 81 inches, width 9 inches, depth 3 inches. This tube formed by subsequent arrangement a portion of the flue through which the air from the furnace passed to the chimney, as is shown in the sketch below, where A represents an iron plate closing the main flue, and compelling the hot air to pass through the iron tube contained in the wooden box, into which water was ultimately placed, as will be explained.



"'Matters being thus arranged, and the iron plate at A securely fixed, it necessarily followed that all the heat from the setting of 8 retorts passed through the 81 inches of iron tube contained in the box, and would therefore impart heat to the water placed in that box, which was filled with this fluid at 71° Fahr. to the extent of 112 lbs. This water being kept in constant motion afforded the annexed thermometric indications.

		Temperature of water.
Commenced experiment at	6·45	71°
Observation made at	6·48	82
"	6·51	94
"	6·54	110
"	6·57	114
"	7·01	132
"	7·06	148
"	7·07	150

Thus showing that 112 lbs. of water were raised 89° in 22 minutes, which is equal to 2·52 lbs. of water at 32° made to boil in each minute. Consequently in 24 hours 3628·8 lbs. of such water might be made to boil, or 604·1 lbs. of water be converted into steam in the same period of time, and as coke will evaporate, according to Lavoisier, more than 10 times its weight of water, this implies the consumption of nearly 60½ lbs. of coke, the heat of which is entirely lost in the chimney. And if this be compared with the total coke consumed for 24 hours in the same setting of retorts, it amounts to about 3 per cent. only, and is therefore under the circumstances remarkably trifling.' Hence it would appear, as has been before remarked, that some very considerable improvements are needed in the present mode of consuming bituminous coals. The probability is, that a flat boiler surface exposed freely to a single sheet of flame from such coals is the best form, for it is certain that long narrow flues act like the meshes of wire gauze upon the volatile constituents, and cool them down below the point at which ignition can go on. In support of this view we have only to recollect that though the gases from a blast furnace will burn freely when they first issue from the furnace and are white hot, yet after being once cooled down to the ordinary temperature they refuse altogether to burn or afford heat. The use of long and narrow flues, with combustibles of low accendibility, is therefore highly improper, and sufficiently explains the miserable results arrived at by the Admiralty coal investigators with a Cornish boiler."—*Mr. L. Thompson.*

FULGURATION; designates the sudden brightening of the melted gold and silver in the cupel of the assayer, when the last film of vitreous lead and copper leaves their surface.

FULLER'S EARTH, (*Terre à foulon, Argile Smectique*, Fr.; *Walkererde*, Germ.) is a soft, friable, coarse or fine grained mass of lithomarge clay. Its colour is greenish, or yellowish gray; it is dull, but assumes a fatty lustre upon pressure with the fingers, feels unctuous, does not adhere to the tongue, and has a specific gravity varying from 1·82 to 2·19. It falls down readily in water, into a fine powder, with extrication of air bubbles, and forms a non-plastic paste. It melts at a high heat into a brown slag Its constituents are 53·0 silica; 10·0 alumina; 9·75 red oxide of iron; 1·25 magnesia; 0·5 lime; 24 water, with a trace of potash. Its cleansing action upon woollen stuffs depends upon its power of absorbing greasy matters. It should be neither tenacious nor sandy; for in the first case, it would not diffuse itself well through water.

and in the second it would abrade the cloth too much. The finely divided silica is one of its useful ingredients.

Fuller's earth is found in several counties of England; but in greatest abundance in Bedfordshire, Berkshire, Hampshire, and Surry.

In the county of Surry there are great quantities of fuller's earth found about Nutfield, Ryegate, and Blechingley, to the south of the Downs, and some, but of inferior quality, near Sutton and Croydon, to the north of them. The most considerable pits are near Nutfield, between which place and Ryegate, particularly on Redhill, about a mile to the east of Ryegate, it lies so near the surface as frequently to be turned up by the wheels of the wagons. The fuller's earth to the north of the road between Redhill and Nutfield, and about a quarter of a mile from the latter place, is very thin; the seam in general is thickest on the swell of the hill to the south of the road. It is not known how long this earth has been dug in Surry; the oldest pit now wrought is said to have lasted between 50 and 60 years, but it is fast wearing out. The seam of fuller's earth dips in different directions. In one, if not in more cases, it inclines to the west with a considerable angle. There are two kinds of it, the blue and the yellow; the former, on the eastern side of the pit, is frequently within a yard of the surface, being covered merely with the soil—a tough, wet, clayey loam. A few yards to the west, the blue kind appears with an irony sand-stone, of nearly two yards in thickness, between it and the soil. The blue earth in this pit is nearly 16 feet deep. In some places the yellow kind is found lying upon the blue; there seems, indeed, to be no regularity either in the position or inclination of the strata where the fuller's earth is found, nor any mark by which its presence could be detected. It seems rather thrown in patches than laid in any continued or regular vein. In the midst of the fuller's earth are often found large pieces of stone of a yellow color, translucent and remarkably heavy, which have been found to be sulphate of barytes, encrusted with quartzose crystals. These are carefully removed from the fuller's earth, as the workmen say they often spoil many tons of it which lie about them. There is also found with the yellow fuller's earth a dark brown crust, which the workmen consider as injurious also. In Surry the price of fuller's earth seems to have varied very little, at least for these last 80 years. In 1730, the price at the pit was 6*d* a sack, and 6*s*. per load or ton. In 1744, it was nearly the same. It is carried in wagons, each drawing from three to four tons, to the beginning of the iron railway near Westham, along which it is taken to the banks of the Thames, where it is sold at the different wharves for about 25*s*. or 26*s*. per ton. It is then shipped off either to the north or west of England.

The next characteristic stratum, owing to its forming a ridge of conspicuous hills through the country, is the Woburn land, a thick ferruginous stratum, which below its middle contains a stratum of fuller's earth. This is thicker and more pure in Aspley and Hogstye-end, two miles north west of Woburn, than in any known place.

Fuller's earth is found at Tillington, and consumed in the neighboring fulling mills.

Mode of preparing fuller's earth:—

After baking it is thrown into cold water, where it falls into powder, and the separation of the coarse from the fine is effectually accomplished, by a simple method used in the dry color manufactories, called washing over. It is done in the following manner: Three or four tubs are connected on a line by spouts from their tops; in the first the earth is beat and stirred, and the water, which is continually running from the first to the last through intermediate ones, carries with it and deposites the fine whilst the coarse settles in the first. The advantages to be derived from this operation are, that the two kinds will be much fitter for their respective purposes of cleansing coarse or fine cloth; for without baking the earth they would be unfit, as before noticed, to incorporate so minutely with the water in its native state; it would neither so readily fall down, nor so easily be divided into different qualities, without the process of washing over. When fuel is scarce for baking the earth, it is broken into pieces of the same size, as mentioned above, and then exposed to the heat of the sun.

The various uses of fuller's earth may be shortly explained. According to the above method, the coarse and fine of one pit being separated, the first is used for cloths of an inferior, and the second for those of a superior quality. The yellow and the blue earths of Surry are of different qualities naturally, and are, like the above, obtained artificially, and used for different purposes. The former, which is deemed the best, is employed in fulling the kerseymeres and finer cloths of Wiltshire and Gloucestershire, whilst the blue is principally sent into Yorkshire for the coarser cloths. Its effect on these cloths is owing to the affinity which alumine has for greasy substances; it unites readily with them, and forms combinations which easily attach themselves to different stuffs, and thereby serve the purpose of mordants in some measure. The fullers generally apply it before they use the soap.

FULLING; for the theory of the process, see Felting and Wool.

FULLING MILL. Willan and Ogle obtained a patent in 1825 for improved ful-

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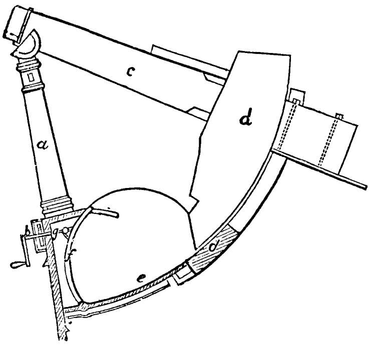

ling machinery, designed to act in a similar way to the ordinary stocks, in which cloths are beaten, for the purpose of washing and thickening them; but the standard and the bed of the stocks are made of iron instead of wood as heretofore; and a steam vessel is placed under the bed, for heating the cloths during the operation of fulling; whereby their appearance is said to be greatly improved.

Fig. 667 is a section of the fulling machine or stocks; *a* is a cast-iron pillar, made hollow for the sake of lightness; *b* is the bed of the stocks, made also of iron, and polished smooth, the side of the stock being removed to show the interior; *c* is the lever that carries the beater *d*. The cloths are to be placed on the bed *b*, at bottom, and water allowed to pass through the stock, when by the repeated blows of the beater *d*, which is raised and let fall in the usual way, the cloths are beaten, and become cleansed and fulled.

A part of the bed at *e*, is made hollow, for the purpose of forming a steam box, into which steam from a boiler is introduced by a pipe with a stop-cock. This steam heats the bed of the stock, and greatly facilitates, as well as improves the process of cleansing and fulling the cloths.

The smoothness of the surface of the polished metal, of which the bed of the stock is constituted, is said to be very much preferable to the roughness of the surface of wood of which ordinary fulling stocks are made, as by these iron stocks less of the nap or felt of the cloth is removed, and its appearance when finished is very much superior to cloths fulled in ordinary stocks.

In the operation of fulling, the cloths are turned over on the bed, by the falling of the beaters, but this turning over of the cloths will depend in a great measure upon the form of the front or breast of the stock. In these improved stocks, therefore, there is a contrivance by which the form of the front may be varied at pleasure, in order to suit cloths of different qualities; *f*, is a moveable curved plate, constituting the front of the stock; its lower part is a cylindrical rod, extending along the entire width of the bed, and being fitted into a recess, forms a hinge joint upon which the curved plate moves; g, is a rod attached to the back of the curved plate *f*, with a screw thread upon it; this rod passes through a nut *h*, and by turning this nut, the rod is moved backward or forward, and consequently the position of the curved plate altered.

The nut *h*, is a wheel with teeth, taking into two other similar toothed wheels, one on each side of it, which are likewise the nuts of similar rods jointed to the back of the curved plate *f;* by turning the central wheel, therefore, which may be done by a winch, the other two wheels are turned also, and the curved plate moved backward or forward. At the upper part of the plate there are pins passing through curved slots, which act as guides when the plate is moved.

The patentees state in conclusion, that steam has been employed before for heating cloths while fulling them, they therefore do not exclusively claim its use, except in the particular way described; the advantages arising from the construction of iron stocks, with polished surfaces in place of wooden ones, together with the moveable curved plates described, are in their opinion "sufficiently important to constitute a patent right."

FULMINATES, or *fulminating powders.* Of these explosive compounds, there are several species; such as fulminating gold, mercury, platinum, silver; besides the old fusible mixture of nitre, sulphur, and potash. The only kind at all interesting in a manufacturing point of view is the fulminate of mercury, now so extensively used as a priming to the caps of percussion locks. Having published a paper in the Journal of the Royal Institution for 1831, upon gunpowder (see GUNPOWDER), the result of an elaborate suite of experiments, I was soon afterwards requested by the Hon. the Board of Ordnance to make such researches as would enable me to answer, in a satisfactory practical manner, a series of questions upon fulminating powders, subservient to the future introduction of percussion muskets into the British army. The following is a verbatim copy of my report upon the subject:—

To the Secretary of the Board of Ordnance.

"SIR,—I have the honor of informing you, for the instruction of the Honorable the Master General and the Board of Ordnance, that the researches on fulminating mercury, which I undertook by their desire, have been brought to a satisfactory conclusion, after a numerous, diversified, and somewhat hazardous series of experiments. The following are the questions submitted to me, with their respective answers:—

Question 1. What proportions of mercury, with nitric acid and alcohol of certain strengths, will yield the greatest quantity of pure fulminate of mercury?

Answer. One hundred parts, by weight, of mercury, must be dissolved with a gentle heat, in 1000 parts (also by weight) of nitric acid, spec. gr. 1·4; and this solution, at the temperature of about 130° Fahr., must be poured into 830 parts by weight of alcohol spec. gr. 0·330.—*Note.* 830 parts of such alcohol, by weight, constitute 1000 by measure; and 1000 parts of such nitric acid, by weight, constitute 740 by measure. Hence, in round numbers, one ounce weight of quicksilver must be dissolved in 7½ oz. measures of the above designated nitric acid, and the resulting solution must be poured into 10 oz measures of the said alcohol.

Question 2. What is the most economical and safe process for conducting the manipulation, either as regards the loss of nitrous gas and residuum, or as respects danger to the operator; also, what is the readiest and safest mode of mixing the fulminate intimately with its due proportions of common gunpowder.

Answer. The mercury should be dissolved in the acid in a glass retort, the beak of which is loosely inserted into a large balloon or bottle of glass or earthenware, whereby the offensive fumes of the nitrous gas disengaged during the solution, are, in a considerable measure, condensed into liquid acid, which should be returned into the retort. As soon as the mercury is all dissolved, and the solution has acquired the prescribed temperature of about 130°, it should be slowly poured, through a glass or porcelain funnel, into the alcohol contained in a glass matrass or bottle capable of holding fully 6 times the bulk of the mixed liquids. In a few minutes bubbles of gas will proceed from the bottom of the liquid; these will gradually increase in number and magnitude till a general fermentative commotion, of a very active kind, is generated, and the mixture assumes a somewhat frothy appearance. A white voluminous gas now issues from the orifice of the matrass, which is very combustible, and must be suffered to escape freely into the air, at a distance from any flame. These fumes consist of an ethereous gas, holding mercury in suspension or combination. I have made many experiments with the view of condensing this gas, or, at least, the mercury, but with manifest disadvantage to the perfection of the process of producing fulminate. When the said gas is transmitted, through a glass tube, into a watery solution of carbonate of soda, a little oxyde of mercury is, no doubt, recovered; but the pressure on the fermentative mixture, though slight, necessary to the displacement of the soda solution, seems to obstruct or impair the generation of the fulminate; this effect is chiefly injurious towards the end of the operation, when the gaseous fumes are strongly impregnated with nitrous gas. When this is not allowed freely to come off, a portion of subnitrate or nitrate of mercury is apt to be formed, to the injury of the general process and the product.

As soon as the effervescence and concomitant emission of gas are observed to cease, the contents of the matrass should be turned out upon a paper double filter, fitted into a glass or porcelain funnel, and washed by the affusion of cold water till the drainings no longer redden litmus paper. The powder adhering to the matrass should be washed out and thrown on the filter by the help of a little water. Whenever the filter is thoroughly drained, it is to be lifted out of the funnel, and opened out on plated copper or stone ware, heated to 212° Fahr. by steam or hot water. The fulminate, being thus dried, is to be put up in paper parcels of about 100 grains each; the whole of which may be afterwards packed away in a tight box, or a bottle with a cork stopper. The excellence of the fulminate may be ascertained by the following characters. It consists of brownish-gray small crystals which sparkle in the sun, are transparent when applied to a slip of glass with a drop of water, and viewed by transmitted light. These minute spangles are entirely soluble in 130 times their weight of boiling water; that is to say, an imperial pint of boiling water will dissolve 67 grs. of pure fulminate. Whatever remains indicates impurity. From that solution beautiful pearly spangles of fulminate fall down as the liquid cools.

It may now be proper to show within what nice and narrow limits the best proportions of the ingredients used in making the fulminate of mercury lie. The following are selected from among many experiments instituted to determine that point, as well as the most economical process.

1. According to the formula given by the celebrated chemist Berzelius, in the 4th vol. of his "Traité de Chimie," recently published (p. 383), the mercury should be dissolved in 12 times its weight of nitric acid, sp. gr. 1·375; and alcohol of sp. gr. 0·850, amounting to 16·3 times the weight of the mercury, should be poured at intervals into the nitric solution. The mixture is then to be heated till effervescence with the characteristic cloud of gas appears. On the action becoming violent, alcohol is to be poured in from time to time to repress it, till additional 16.3 parts have been employed.

On this process I may remark, that it is expensive, troublesome, dangerous, and unproductive of genuine pure fulminate. One fifth more nitric acid is expended very nearly than what is necessary, and almost four times the weight of alcohol which is beneficial. Of alcohol at 0·83, 8·3 parts by weight are sufficient; whereas Berzelius prescribes nearly 4 times this quantity in weight, though the alcohol is somewhat weaker being of sp. gr. 0·850. By using such an excess of alcohol, much of the fulminate is apt to be revived into globules of quicksilver at the end of the process, as I showed in my paper on this subject published in the Journal of the Royal Institution two years ago. There is no little hazard in pouring the alcohol into the nitric solution; for at each affusion an explosive blast takes place, whereas by pouring the solution into the alcohol, as originally enjoined by the Hon. Mr. Howard, the inventor of the process, no danger whatever is incurred. 100 parts of mercury treated in the way recommended by Berzelius afforded me only 112 parts of fulminate. instead of the 130 obtained by my much more economical and safe proportions and process from the same weight of quicksilver.

2. If 10 parts of nitric acid of sp. gr. 1·375 be used for dissolving 1 of quicksilver, and if 14 parts of alcohol of sp. gr. 0·85 be thereafter mixed with the solution, the product of such proportions will either be not granular, and therefore not fulminating, or it will be partially granular and partially pulverulent, being a mixture of fulminate and subnitrate of mercury ill adapted for priming detonating caps. Instead of 130 parts of genuine fulminate, as I do obtain, probably not more than 10 parts of powder will be produced, and that of indifferent quality. In fact, whenever the ethereous fermentation is defective, or not vigorous, little true fulminate is generated; but much of the mercury remains in the acidulated alcoholic liquid.

3. If the alcohol be poured in successive portions, and of proper strength (sp. gr. 0·83), into a proper nitric solution of mercury, the explosive action which accompanies each affusion dissipates much of the alcohol, and probably impairs the acid, so that the subsequent ethereous fermentation is defective, and little good fulminate is formed. From 100 parts of mercury submitted to this treatment, I obtained in one experiment, carefully made, only 51 parts of a powder, which was impalpable, had a cream color, and was not explosive either by heat or percussion.

4. When, with 100 parts of mercury. 800 of nitric acid of sp. gr. 1·375, are employed with 650 of alcohol of sp. gr. ·846. no fulminate whatever is generated.

5. When, with the proper proportions of mercury, acid, and alcohol, the process is advanced into a proper energy of fermentative commotion, if the matrass be immersed in cold water so as materially to repress that action, the process will be impaired, and will turn out ultimately defective both as to the quantity and quality of the fulminate. It is therefore evident that a certain energy or vivacity of etherization is essential to the full success of this curious process, and that anything which checks it, or obstructs its taking place, is injurious and to be avoided.

When my proportions are observed in making fulminating mercury, somewhat less than one fourth of the nitric acid used in making the solution remains in the alcoholic mixture along with the fulminate. When other proportions are taken, much more acid remains. This acid is not recoverable to any useful or economical purpose, nor is the alcohol that is associated with it. Many distillations, with various reagents, have led me to this practical conclusion. In fact, when the process is most complete, as described in the first paragraph, the alcohol is entirely and profitably employed in etherization, an generating fulminic acid.

I have made a series of analytical experiments on the pure fulminate of mercury, with the view of determining its composition, the quantity of quicksilver present in it, and consequently the loss of mercury in the operation. I have stated that my maximum product of fulminate from 100 grs. of quicksilver is 130 grs. Occasionally, from slight differences in the temperature of the mixture, or the ambient atmosphere, 2 grs. less may be obtained.

A. I dissolved 130 grs. with a gentle heat in muriatic acid contained in a small matrass, adding a few drops of the nitric to quicken the solution. On evaporating it to dryness, with much care to avoid volatilization of the salt, I obtained 125 grs. of corrosive sublimate or bi-chloride of mercury. But 125 grs. of this bi-chloride contain only 91·1 grs. of quicksilver. Therefore, by this experiment, 130 grs. of fulminate contain no more than 91·1 of mercury, indicating an exhalation of 8·9 parts in the form of fumes, or a retention in the residuary liquid of some of these 8·9 parts, out of the 100 originally employed.

B. In another experiment for analysis, 130 grs. dissolved as above, were thrown down by carbonate of soda. 95 grs. of black oxyde of mercury were obtained, which are equivalent to 91·2 grs. of quicksilver; affording a confirmation of the preceding result.

C. 130 grs. of fulminate were dissolved in strong muriatic acid, and the solution was decomposed by crystals of proto-muriate of tin at a boiling temperature. The mercury was precipitated in globules to such amount as to verify the two preceding experiments.

Regarding fulminate of mercury as a bi cyanate, that is, as a compound of one atom or one equivalent prime of deutoxyde of mercury, and two primes of cyanic acid, we shall find its theoretical composition to be as follows, hydrogen being the radix, or 1.

2 primes of Cyanic or Fulminic Acid = 34 × 2 =	68	24
Deutoxyde of Mercury =	216	76
	284	100

As these 284 parts of fulminate contain 200 of quicksilver, so 142 parts of fulminate will contain 100 of quicksilver. Whence it appears, that when only 130 parts of fulminate can be obtained in practice from 100 of quicksilver, 8½ parts of quicksilver out of the 100 are unproductive, that is, are expended in the etherized gas, or left in the residuary acidulous liquid. By the above experimental and theoretical analysis 91·5 parts of quicksilver enter into the composition of 130 parts of true crystalline fulminate. The complete accordance here exhibited between theory and practice removes every shadow of doubt as to the accuracy of the statements. 100 parts of fulminate consist of—

Mercury	70·4	Peroxyde 76·0
Oxygen	5·6	
Fulminic acid -		24
		00 0

Question 3. May the gas or vapor produced by the inflammation of the fulminate of mercury, when combined with a portion of gunpowder, be considered in its nature corrosive of iron or brass?

Answer. I have suggested to Mr. Lovell, of Waltham Abbey works, that the fulminate may be probably diluted most advantageously with spirit varnish made of a proper consistence by dissolving sandarach in alcohol. When well mixed with this varnish, a small drop of the mixture will suffice for priming each copper cap or disc; and as the spirit evaporates immediately, the fulminate will be fixed to the copper beyond the risk of shaking or washing away. On the Continent, tincture of benjamin is used for the same purpose; but as that balsamic resin leaves in combustion a voluminous coal, which sandarach does not, the latter, which is the main constituent of spirit varnish, seems better adapted for this purpose. It is sufficiently combustible, and may be yet made, by a due proportion, to soften the violence of the explosive mercury on the nipple of the touch-hole. Fulminate prepared by my formula has no corrosive influence whatsoever on iron or steel; and, therefore, if such a medium of applying it, as I have now taken leave to suggest, should be found to answer, all fears on the score of corrosion may for ever be set at rest.

Question 4. How far is the mixture (of fulminate and gunpowder) liable to be affected by the moisture of the atmosphere, or by the intrusion of water; and will such an accident affect its inflammability when dried again?

Answer. Well made fulminate, mixed with gunpowder and moistened, undergoes no change, nor is it apt to get deteriorated by keeping any length of time in a damp climate or a hazy atmosphere. Immersion in water would be apt to wash the nitre out of the pulverine; but this result would be prevented if the match or priming mixture were liquefied or brought to the pasty consistence, not with water, but spirit varnish. Such detonating caps would be indestructible, and might be alternately moistened and dried without injury.

Question 5. Is it at all probable that the composition would be rendered more inflammable or dangerous of use by the heat of tropical climates?

Answer. No elevation of temperature of an atmospheric kind, compatible with human existence, could cause spontaneous combustion of the fulminating mercury, or the detonating matches made with it. In fact, its explosive temperature is so high as 367° of Fahrenheit's scale, and no inferior heat will cause its detonation.

Question 6. Is the mercurial vapor or gas arising from the ignition of a great number of primers, and combined with the smoke of gunpowder in a confined space (as in the case of troops in close bodies, squares, casemates, &c.), likely in its nature to be found prejudicial to human health?

Answer. I have exploded in rapid succession of portions, 100 grains of fulminate of mercury (equivalent to 300 or 400 primers), in a close chamber of small dimensions, without experiencing the slightest inconvenience at the period, or afterwards, though my head was surrounded by the vapors all the time of the operation. These vapors are, in fact, so heavy that they subside almost immediately. When the fulminate mixed with pulverine is exploded in the primers by condensed masses of troops, the mercury will cause no injury to their health, nor 100th part of the deleterious impression on weak lungs which the gases of exploded gunpowder might by possibility inflict. These gases are all, *theoretically* speaking, noxious to respiration; such as carbonic acid gas, azote, carbureted hydrogen, and sulphureted hydrogen, a deadly gas. Yet the soldier who should betray any fear of gunpowder smoke would be an object of just ridicule."

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In the following September, I executed for the Board of Ordnance a set of experiments, complementary to those of the memoir, with the view of ascertaining the best manner of protecting the fulminate when applied to the copper caps, from being detached by carriage, or altered by keeping. The following were my results and conclusions.

"1. Fulminate of mercury moistened upon copper is speedily decomposed by the superior affinity of the copper over mercury, for oxygen and fulminic acid. Dryness is, therefore, essential to the preservation of the fulminate; and hence charcoal, which is apt to become moist, should not be introduced into percussion caps destined for distant service.

2. An alcoholic solution of sandarach, commonly called spirit varnish, acts powerfully on copper, with the production of a green efflorescence, which decomposes fulminate of mercury. Indeed, sandarach can decompose the salts of copper. It is therefore ill adapted for attaching the fulminate to copper caps.

3. An alcoholic solution of shellac acts on copper, though more feebly than the sandarach.

4. A solution of mastic in spirits of turpentine, whether alone or mixed with fulminate, has no action whatever on bright copper, but protects it from being tarnished. Such a varnish is very cheap, dries readily, adheres strongly, screens the fulminate from damp, and does not impair or counteract its detonating powers. This, therefore, is, in my opinion, the fittest medium for attaching the fulminate, and for softening the force of its impulsion in any degree preportional to the thickness of the varnish."

Fulminate of mercury is obtained in white grains, or short needles, of a silky lustre, which become gray upon exposure to light, and detonate either by a blow or at a heat under 370° F.; with the disengagement of azote, carbonic acid, as also of aqueous and mercurial vapors; to the sudden formation of which gaseous products the report is due. It detonates even in a moist condition; and when dry it explodes readily when struck between two pieces of iron, less so between iron and bronze, with more difficulty between marble and glass, or between two surfaces of marble or glass. It is hardly possible to explode it by a blow with iron upon lead; and impossible by striking it with iron upon wood. It fulminates easily when rubbed between two wooden surfaces; less so between two of marble, two of iron, or one of iron against one of wood or marble. The larger its crystals, the more apt they are to explode. By damping it with 5 per cent. of water, it becomes less fulminating; the part of it struck still explodes with a proper blow, but will not kindle the adjoining portion. Though moistened with 30 per cent. of water, it will occasionally explode by trituration between a wooden muller and a marble slab, but only to a small extent, and never with any danger to the operator. When an ounce of it, laid upon the bottom of a cask, is kindled, it strikes a round hole down through it, as if it had been exposed to a four-pound shot, without splintering the wood. If a train of fulminate of mercury be spread upon a piece of paper, covered with some loose gunpowder, in exploding the former the latter will not be kindled, but merely scattered. When gunpowder, however, is packed in a cartridge, or otherwise, it may be certainly kindled by a percussion cap of the fulminate, and more completely than by a priming of gunpowder. 8½ parts of gunpowder exploded by a percussion cap, have an equal projectile force as 10 exploded by a flint lock. If we add to this economy in the charge of the barrel, the saving of the powder for priming, the advantage in military service of the percussion system will become conspicuous.

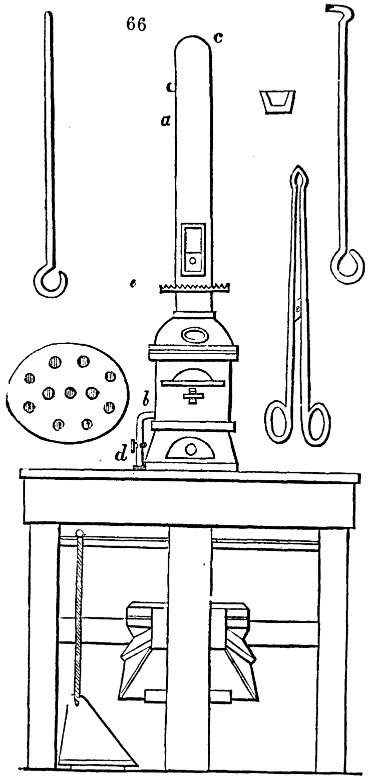
The French calculate that 1 kilogramme of mercury will furnish 1¼ kil. (2½ lbs. nearly) of fulminate, which will be sufficient to charge 40,000 percussion caps. For this purpose they grind the crystalline salt along with 30 per cent. of water upon a marble table with a wooden muller; mixing with every 10 parts of the fulminate 6 of gunpowder. A consistent dough is thus obtained, which, being dried in the air, is ready for introducing into the bottoms of the copper caps. One quarter of a grain of the fulminate is said to be fully sufficient for one priming.

Mr. Lovell, of the Royal Manufactory of Arms, has lately executed a series of experiments upon priming powders. His trials, which occupied nearly 18 months, were made for the purpose of ascertaining what is the advantage in point of *force* obtained by using percussion primes. He had anticipated some extra energy would be imparted to the charge of powder in the barrel, because he had repeatedly proved that a good strong cap, exploded by itself on the nipple of the musket (without any charge of gunpowder), will exert sufficient force upon the air within the barrel to blow a candle out at a distance of 12 feet from the muzzle. He concluded also that stopping the escape of fluid from the vent, as is done by the cap, would have some effect, but he attributed most to the quickness and energy with which the powder of the charge is ignited by the vivid stream of flame, generated by the percussion prime. The trials were made from one and the same barrel, having a percussion lock on one side and a flint lock on the other. The balls were fired against Austen's recoiling target, a very delicate *plegometer*, beginning with a charge of 150 grains (the present musket charge), and descending by 10 grains at a time (firing descending by 10 grains at a time (firing 30 rounds with each weight), down to 50 grains. The machine marked the decrease of force at each reduction in the charge very satisfactorily, and the result of the whole average was that 8·84 parts of gunpowder fired by percussion are equal to 10 parts fired by the flint.

To find out what sort of liberties might be taken with fulminate of mercury in handling it, he placed 3 grains on an anvil, putting the end of a steel punch gently on the top of it, and while so placed he covered the fulminate over with a drachm of dry gunpowder. He then ignited the fulminate by a blow on the punch with the hammer, but not a grain of the gunpowder was lighted, though it was blown about in all directions. He then placed a train of fulminate as thick as a quill, and about 3 feet long, on a table, and covered it over entirely with gunpowder except about an inch at one end; this he lighted with hot iron, when the whole train went off without blazing a grain of the gunpowder, which he swept together and blew up afterwards with a match. He then took a tin box containing 500 copper caps, made a hole in the top of the box, and through this hole ignited one of the caps in the middle, by means of the punch and hammer on the outside; only two other caps besides the one struck exploded; no injury was sustained by the remainder, except being discoloured. This he tried repeatedly, and always with the same kind of result, never more than 3 or 4 caps exploding. He then made a steel rammer red hot, and passed it through the hole in the box right in amongst the caps, but it only ignited them where the iron came in actual contact with the priming composition; when, however, he placed a few grains of gunpowder loose among the caps, the hot iron lighted this, and produced a flame that blew off the whole of them.

The same thing has been tried at Woolwich, where large packages of percussion caps (some thousands) have been fired at with musquet balls, and only a few of the caps actually hit by the ball exploded; but when any cartridges were connected with the packages, the whole, caps and all, were blown up. The flame of the fulminate is therefore hazardous, but being so very ethereal, it requires for making primes an admixture of some combustible matter, as a little gunpowder, to condense or modify the flame.

66



FULMINIC ACID; (*Acid fulminique*, Fr.; *Knallsaure*, Germ.) is the explosive constituent of the fulminating mercury of Howard, and the fulminating silver of Brugnatelli, being generated by the reaction of alcohol and the acid nitrates of these metals. It is a remarkable chemical fact, that fulminic acid has exactly the same composition as cyanic acid; though the salts of the latter possess no detonating property, and afford, in their decomposition by an oxygen acid, ammonia with carbonic acid; while those of the former afford ammonia and prussic acid. All attempts to insulate fulminic acid have proved unsuccessful, as it explodes with the slightest decomposing force. It consists, by weight, of 2 primes of carbon, 1 of azote, and 1 of oxygen; or of two volumes of carbonic acid, and one of azote. When two different bodies, like the above, have the same composition, they are said to be *isomeric*.

FUMIGATION, is the employment of fumes or vapours to purify articles of apparel, and goods or apartments supposed to be imbued with some infectious or contagious poison or fumes. The vapours of vinegar, the fumes of burning sulphur, explosion of gunpowder, have been long prescribed and practised, but they have in all probability little or no efficacy. The diffusion of such powerful agents as chlorine gas, muriatic acid gas, or nitric acid vapour, should alone be trusted to for the destruction of morbific effluvia.

FUR; see PELTRY.

FURNACE OF ASSAY. Under ASSAY, I have referred to a furnace constructed by Messrs. Anfrye and d'Arcet which gives some peculiar facilities and economy to the ancient process by fire. It had originally a small pair of bellows attached to it, for raising the heat rapidly to the proper vitrifying pitch. The furnace, 17½ inches high, and 7½ inches wide, made of pottery or fine clay, is represented *fig.* 668., supported upon a table, having a pair of bellows beneath it. The laboratory is at *b*, the blow-pipe of the bellows at *d*, with a stop-cock, and the dome is surmounted by a chimney *a*, *c*, in whose lower part there is an opening with a sliding door, for the introduction of the charcoal fuel. The furnace is formed in three pieces; a dome, a body, and an ash-pit. A pair of tongs, a stoking-hook, and cupel, are seen to the right hand, and the plan of the stone-ware grate, pierced with conical holes, and a poker, are seen to the left. This grate suits the furnace represented under Assay. The following are comparative experiments made by means of this furnace:

Numbers.	Silver employed.	Lead employed.	Time of Assay.	Standards.	Charcoal used.
1	1 Grain	4 Grains.	12 minutes.	947 millièmes.	173 Grains.
2	—	—	11	950	86
3	—	—	13	949	93
4	—	—	10	949	60

Each assay was therefore performed at an average in 11½ minutes, and not much more than a quarter of a pound of charcoal was used. An experiment of verification in the ordinary assay furnace showed the standard to be 949 thousandths.

This furnace becomes a very convenient one for melting small quantities of metals in analyses, by removing the muffle, and closing the several apertures with their appropriate stoppers. A small pedestal may be then set in the middle of the grate, to support a crucible, which may be introduced through the opening *h*. Coke may also be used as fuel, either by itself or mixed with charcoal. For descriptions of various furnaces, see Assay; Beer; Copper; Evaporation; Iron; Metallurgy; Ores; Silver; Tin, &c.

FUR-SKIN DRESSING. Fur-skins are usually dressed by placing them in their dried state in tubs, where they undergo a treading operation with men's feet, until they are sufficiently soft and bend easily. The skins if large are sewn up, the fur being turned inwards; but if small skins, such as ermine, are being dressed, they require no sewing. This sewing is preparatory to the greasing with butter or lard, and is intended to protect the fur from the grease, and to promote the softening in the succeeding treading operation. The skins are next wetted, and their flesh is removed; or they are fleshed and then hung up to dry. They are again subjected to treading in tubs containing sawdust; and afterwards in tubs containing plaster of Paris, or whitening, sprinkled between the skins. They are then beaten with a stick, and combed; when the dressing is completed. M. Pierre Thirion proposes, in his patent of June, 1845, to soften the skins, not by treading, but by beating stocks, of a construction like the fulling mill. They are next sewn up, and again fulled in a strong vessel, where they are forced upwards by the beaters, turned over and over, and thus speedily softened. They are now fleshed, and then returned to the beating stocks, and mahogany or other sawdust is sprinkled upon the fur, before the beating is renewed. They are next placed in a heated barrel, furnished within with radial pins for turning the goods over and over, in order that they may be acted upon by various dry substances, which are thrown into the barrel, and absorb the fat from the skins. Through the hollow shaft of the barrel, steam is introduced, which heats the skins, softening the fat, which is then absorbed by sand, flour, or any other desiccative powder. It is proper to take the skins out of the barrel from time to time to comb them. Such as have been sufficiently acted upon may then be set aside. They are lastly freed from the dust by being subjected to a grated cylinder in a state of rotation, and then combed by hand.

FUSEL OIL is the German name of the offensive smelling oil which exists in alcohol, as distilled from the fermented infusions of malt, and corn meal of all kinds, as also from the fermented wash of potatoes, and of beets, &c. A like oil occurs in the alcohol distilled from the fermented must of grapes, and the juices of many sweet fruits. This oil is not, however, identical from these several sources; as may indeed be inferred from the diversity in the flavours of the different liquors. But they all agree in being somewhat less volatile than water, and therefore make their appearance chiefly in the spirits towards the end of the distillation process. It is to the presence of this oil that the milkiness of the last, and also sometimes of the first, portions of the spirit that come over, called feints, owe their opalescence and their penetrating odour. When the milky fluid is redistilled, alcohol and water first pass over with very little oil, but if the heat of the still be moderate, the oil may be made a residuum, and obtained in a tolerably concentrated state. The oil from potatoes was first analyzed by Dumas, and was shown by him to be composed of 68·2 per cent. of carbon, 13·6 of hydrogen, and 18·2 of oxygen; according to the formula $C_{10}H_{11}O.\ HO$. It belongs therefore to the class of

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alcohols, one whose radical is $C_{10}H_{11}$, or *amyle*, and is an amyl oxyhydrate; just as common alcohol is an oxyhydrate of ethyle. The potato amyle spirit is a colourless fluid of an acrid burning taste, and of a most offensive, penetrating, durable smell. When the vapour of it is inhaled it produces an oppressive nausea, headache, giddiness, and retching. It has a poisonous action on the animal system. By oxydizing agents it is converted into valerianic (Baldrian) acid. According to Balard the amyle spirit occurs along with the œnanthic ether in the oil, which contaminates brandy, and is probably derived from the husks of the grapes. This noxious spirit exists most abundantly in the whisky of malt, and especially in that from raw grain; and is now an article of considerable sale, being used to burn in lamps, to dissolve copal and other resins for varnish making and other purposes.

Besides this liquid amyle spirit corn spirits contain a concrete fatty matter, of a brown colour, an acid reaction, and an offensive smell and taste. It has a green tinge, which I believe is derived from the copper worm of the still. Mulder has shown that this fatty product consists of an easily fusible and a difficultly fusible portion. The former he regards as the ether of œnanthic acid; consisting of 85 carbon, 10·3 hydrogen, and 4·8 oxygen, and is therefore quite different from the amyle spirit. Margaric acid is mixed with the less fusible portion. He says that one million parts of malt whisky contain 30 of œnanthic acid, 9 of œnanthic ether, and 5 of corn oil (amyle spirit). There are probably many varieties of these oils of crude alcohol.

FUSIBILITY. That property by which solids assume the fluid state.

Some chemists have asserted that fusion is simply a solution in caloric; but this opinion includes too many yet undecided questions, to be hastily adopted.

Fusibility of Metals, as given by M. Thenard.

		Centigr.	
1. Fusible below a red heat.	Mercury	—39°	
	Potassium	+58°	Gay Lussac and Thenard.
	Sodium	90	
	Tin	210	Newton.
	Bismuth	256	
	Lead	260	Biot.
	Tellurium	A little less fusible than lead.—**Klaproth.**	
	Arsenic	Undetermined.	
	Zinc	370°	Brongniart.
	Antimony	A little below a read heat.	
	Cadmium		Stromeyer.
		Pyrometer of Wedgewood.	
2. Infusible below a red heat.	Silver	20	Kennedy.
	Copper	27	Wedgewood.
	Gold	32	
	Cobalt	A little less difficult to melt than iron.	
	Iron	130	Wedgewood.
		158	Sir G. M'Kenzie.
	Manganese	160	Guyton.
	Nickel		As manganese.—Richter.
	Palladium Molybdenum Uranium Tungsten Chromium	Nearly infusible; and to be obtained at a forge heat only in small buttons.	
	Titanium Cerium Osmium Iridium Rhodium Platinum Columbium	Infusible at the forge furnace. Fusible at the oxyhydrogen blowpipe. See BLOWPIPE.	

FUSIBLE METAL. See ALLOY.

FUSTET. (*Fustec*, Fr.) The wood of the *rhus cotinus*, a fugitive yellow dye.

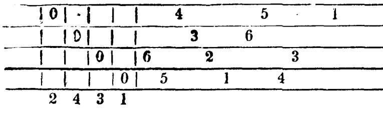
FUSTIAN is a species of coarse thick tweeled cotton, and is generally dyed of an olive, leaden, or other dark color. Besides the common fustian, which is known by the name of pillow (probably pilaw), the cotton stuffs called corduroy, velverett, velveteen, thicksett, used for men's wearing apparel, belong to the same fabric. The commonest kind is merely a tweel of four, or sometimes five leaves, of a very close stout texture, and very narrow, seldom exceeding 17 or 18 inches in breadth. It is cut from the loom in half pieces, or ends, as they are usually termed, about 35 yards long, and after undergoing the subsequent operations of dyeing, dressing, and folding, is ready for the market

The draught and cording of common fustian is very simple, being generally a regular or unbroken tweel of four or five leaves. Below are specimens of a few different kinds, selected from those most general in Lancashire.

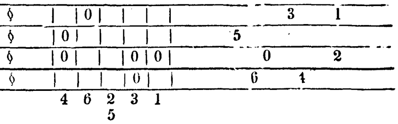
The number of leaves of heddles are represented by the lines across the paper, and the *cording* by the ciphers in the little squares, those which raise every leaf being distinguished by these marks, and those which sink them left blank, as more particularly explained in the article Textile Fabric.

Of velvet, there are properly only two kinds, that with a plain, and that with a tweeled, or, as it is here called, a Genoa ground, or back. When the material is silk, it is called velvet, when cotton, velveteen; and this is the sole difference. In the same way a common tweeled cloth, when composed of silk is called satin; when of cotton, fustian or jean; of woollen, plaiding, serge, or kerseymere; and in the linen trade is distinguished by a variety of names according to the quality or fineness, or the place where the article is manufactured.

No. 1.—Pillow Fustian.

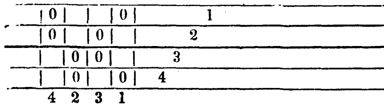


No. 2.—Plain Velveret.

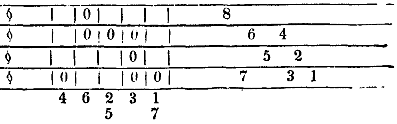


Of the above, each contains four leaves of heddles or healds; that represented by No. 1 is wrought by four treddles, and that which is distinguished by No. 2 by five; the succession of inserting the threads of warp into the heddles will be discovered by the figures between the lines, and the order in which the treddles are to be successively pressed down by the figures below.

No. 3.—Double Jean.

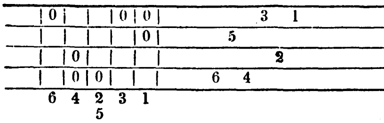


No. 4.—Plain Thickset.

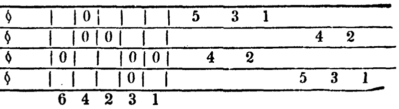


These, like the former, are wrought with leaves. No. 3 requires four, and No. 4 five treddles. The succession of inserting the threads of warp, and of working the treddles, are marked by the respective numbers between and under the lines, as in the former example. Both are fabrics of cloth in very general use and estimation as low priced articles.

No. 5.—Best Thickset.

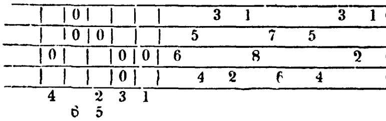


No. 6.—Velvet Tuft.

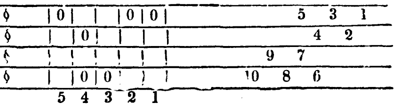


These are further specimens of what may be, and is, executed with four leaves, and in both examples five treddles are used. With two other specimens we shall conclude our examples of this description of work, and shall then add a very few specimens of the more extensive kinds.

No. 7.—Cord and Velveret.

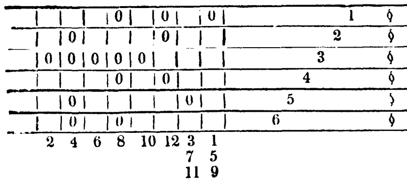


No. 8.—Thickset Cord.

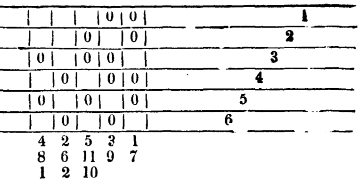


In these the succession of drawing and working are marked like the former. The next are examples of patterns wrought with six leaves. No. 9 has eight, and No. 10 five heddles

No. 9.—Double Corduroy.



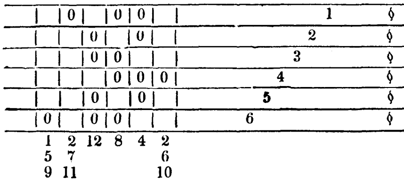
No. 10.—Genoa Thickset.



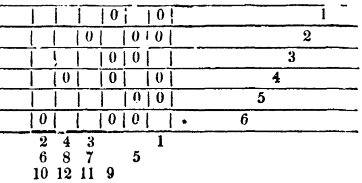
In both these the warp is inserted into the heddles the same way. The difference is entirely in the application of the cords, and in the succession of pressing down the treddles. We now give four specimens of the flushed and cut work, known by the name of velveteen. They are also upon six leaves, and the difference is solely in the cording and in the treading.

Queen's Velveteens.

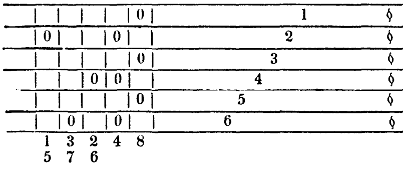
No. 11.



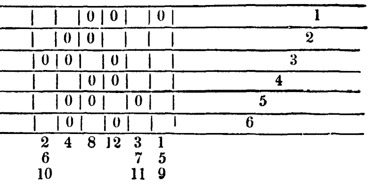
No. 12.



No. 13.—Plain Velveteen.

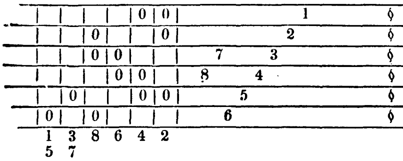


No. 14.—Genoa Velveteen.

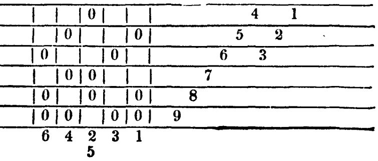


The additional varieties of figure which might be given are almost endless, but the limits of this article will not admit a further detail. Those already given are the articles in most general use. The varieties of fancy may be indulged to a great extent; but it is universally found, that the most simple patterns in every department of ornamental weaving are those which attract attention and command purchasers. We shall therefore only add two examples of king's cord or corduroy, two of Genoa and common velvet, and two more of jean. These will be found below.

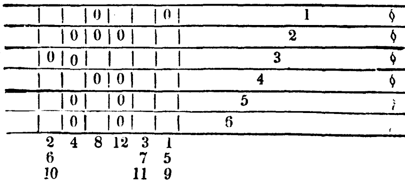
No. 15.—King's Cord.



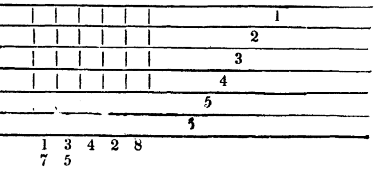
No. 16.—Dutch Cord.



No. 17.—Genoa Velvet.



No. 18.—Plain Velvet.



After the fustian cloth is taken from the loom beam, it is carried to the cutter, who rips up the surface-threads of weft, and produces thereby a hairy-looking stuff.

Preparatory to its being cut, the cloth is spread evenly upon a table about six feet long, upon each end of which a roller mounted with a ratchet-wheel is fixed; the one to give off, and the other to wind up the piece, in the above six-feet lengths.

The knife is a steel rod about two feet long, and three eighths of an inch square, having a square handle at the one end; the other end is tapered away to a blade, as thin as paper. To prevent this point from turning downwards and injuring the cloth, its under side is covered by a guide which serves to stiffen it, as well as to prevent its lower edge from cutting the fustian.

The operative (male or female) grasps the handle in the right hand, and insinuating the projecting point of the guide under the weft, pushes the knife smartly forward through the whole length of six feet, with a certain dexterous movement of the shoulder and right side, balancing the body meanwhile, like a fencer, upon the left foot. This process is repeated upon every adhesive line of the weft.

The next process to which fustians are exposed is steeping in hot water, to take out the dressing paste. They are then dried, reeled, and brushed by a machine, &c. From twenty to thirty pieces, each eighty yards long, may be brushed in an hour. The breadth of the cloth is twenty inches. The maceration is performed by immersing the bundled pieces in tanks of water, heated by waste steam; and the washing by means of a reel or winch, kept revolving rapidly under the action of a stream of cold water, for an hour or longer.

After being thus ripped up, it is taken to the brushing or teazling machine, to make it shaggy.

This consists of a series of wooden rollers, turning freely upon iron axles, and covered with tin-plate, rough with the burs of punched holes; and blocks of wood, whose concave under surfaces are covered with card-cloth or card-brushes, and which are made to traverse backwards and forwards in the direction of the axes of the revolving rollers, during the passage of the cloth over them.

After they are brushed in the machine, the goods are singed by passing their cut surface over a cylinder of iron, laid in a horizontal direction, and kept red hot by a flue. See SINGEING. They are now brushed again by the machine, and once more passed over the singeing surface. The brushing and singeing are repeated a third, or even occasionally a fourth time, till the cord acquires a smooth polished appearance.

The goods are next steeped, washed, and bleached, by immersion in solution of chloride of lime. They are then dyed by appropriate chemical means. After which they are padded (imbued by the padding machine of the calico printers) with a solution of glue, and passed over steam cylinders to stiffen them.

Smooth fustians, when cropped or shorn before dyeing, are called moleskins; but when shorn after being dyed, are called beaverteen: they are both tweeled fabrics. Cantoon is a fustian with a fine cord visible upon the one side, and a satiny surface of yarns running at right angles to the cords upon the other side. The satiny side is sometimes smoothed by singeing. The stuff is strong, and has a very fine aspect. Its price is one shilling and sixpence a yard.

Common plain fustian, of a brown or drab color, with satin top, is sold as low as sevenpence a yard.

A fustian, with a small cord running in an oblique direction, has a very agreeable appearance. It is called diagonal. Moleskin shorn, of a very strong texture, and a drab dyed tint, is sold at 20*d.* per yard.

The weight of 90 yards of the narrow velveteen, in the green or undressed state, is about 24 pounds. The goods made for the German, Italian, and Russian markets are lighter, on account of the peculiarity in the mode of levying the import duty in these countries.

Velveteens as they come from the loom, are sold wholesale by weight, and average a price of 20*d.* per pound. They are usually woven with yarns of Upland and Brazil cotton wool, spun together for the warp; or, sometimes, New Orleans alone. The weft is usually Upland, sometimes mixed with East India cotton wools.

Trouser velveteens are woven 19 inches wide, if they are to be cut up; if not, they are woven 30 inches, and called beaverteen.

Cutting or cropping fustians by hand is a very laborious and delicate operation. The invention of an improved apparatus for effecting the same end with automatic precision and despatch, was therefore an object of no little interest to this peculiar manufacture of Manchester. An ingenious machine, apparently well calculated for this purpose, was made the subject of a patent by Messrs. William Wells and George Scholefield, of Salford, in November, 1834.

FUSTIC. (*Bois jaune*, Fr.; *Gelbholz*, Germ.) The *old* fustic of the English dyer, as the article fustet is their *yellow* fustic. It is the wood of the Morus tinctoria. It is light, not hard, and pale yellow with orange veins; it contains two coloring matters, one resinous, and another soluble in water. The latter resembles weld, but it has more of an orange cast, and is not so lively.

Its decoctions in water are brightened by the addition of a little glue, and more by curdled milk. This wood is rich in color, and imparts permanent dyes to woollen stuffs, when aided by proper mordants. It unites well with the blue of the indigo vat, and Saxon blue, in producing green of various shades. Alum, tartar, and sólution of tin, render its color more vivid; sea salt and sulphate of iron deepen its hue. From 5 to 6 parts of old fustic are sufficient to give a lemon color to 16 parts of cloth. The color of weld is however purer and less inclining to orange; but that of fustic is less affected by acids than any other yellow dye. This wood is often employed with sulphate of iron in producing olive and brownish tints, which agree well with its dull yellow. For the same reason it is much used for dark greens.

G.

GABRONITE is a yellowish stony substance, of a greasy lustre and spec. gr.=2·74; affording no water by calcination; fusible at the blowpipe into an opaque glass; soluble in muriatic acid; solution affords hardly any precipitate by oxalate of ammonia. This mineral is distinguished by the large quantity of soda which it contains; its constituents being—silica, 54; alumina, 24; soda, 17·25; magnesia, 1·5; oxyde of iron, 1·25; water, 2. It belongs to the species Nepheline.

GADOLINITE, called also Yttrite and Ytterbite, is a mineral of a black, brownish, or yellowish color, granular, or compactly vitreous, and conchoidal fracture; of spec. grav. 4·23; readily scratching glass; fusible at the blowpipe into an opaque glass, sometimes with intumescence. It affords, with acids, a solution that lets fall, with caustic soda, a precipitate partly re-soluble in carbonate of ammonia. It is remarkable for containing from 45 to 55 per cent. of the earth Yttria; its remaining constituents being silica, 25·8; oxyde of cerium, 17·92; oxyde of iron, 11·43. This mineral is very rare, having been hitherto found only in the neighborhood of Fahlon and Ytterby, in Sweden; its peculiar constituent was discovered by Professor Gadolin.

GALACTOMETER, or LACTOMETER, is an instrument to ascertain the quality of milk; an article often sophisticated in various ways. Fresh milk, rich in cream, has a less specific gravity than the same milk after it has been skimmed; and milk diluted with water becomes proportionably lighter. Hence, when our purpose is to determine the quantity of cream, the galactometer may consist merely of a long graduated glass tube standing upright upon a sole. Having filled 100 measures with the recent milk, we shall see, by the measures of cream thrown up, its value in this respect. A delicate long-ranged glass hydrometer, graduated from 1·000 up to 1·060, affords the most convenient means of detecting the degree of watery dilution, provided the absence of thickening materials has been previously ascertained by filtration. Good fresh milk indicates from 1·030 to 1·032; when the cream is removed, 1·035 to 1·037. When its density is less than 1·028, we may infer it has been thinned with water.

GALBANUM is a gum-resin, which occurs sometimes in yellow, shining tears, easily agglutinated; of a strong durable smell; an acrid and bitter taste; at other times in lumps. It exudes either spontaneously or from incisions made into the stem of the *bubon galbanum*, a plant of the family of *umbelliferæ*, which grows in Africa, particularly in Ethiopia. It contains 67 of resin; 19·3 of gum; 6·4 of volatile oil and water; 7·5 of woody fibres and other impurities; with traces of acid malate of lime.

GALENA, (*Plomb sulfuré*, Fr.; *Bleiglanz*, Germ.;) is a metallic looking substance of a lead-gray color, which crystallizes in the cubical system, and is susceptible of cleavages parallel to the faces of the cube; spec. gr. 7·7592; cannot be cut; fusible at the blowpipe with exhalation of sulphureous vapors; is easily reduced to metallic lead. Nitric acid first dissolves it, and then throws down sulphate of lead in a white precipitate; the solution affording, with plates of zinc, brilliant laminæ of lead (arbor Saturni.) It consists of sulphur, 13; lead, 85; with a little iron, and sometimes a minute quantity of silver. This is the richest ore of lead, and it occurs in almost every geological formation, in veins, in masses, or in beds. It is almost always accompanied by sulphuret of zinc, different salts of lead, heavy spar, fluor spar, &c. Galena in powder, called Alquifoux, is employed as a glaze for coarse stoneware.

GALIPOT is a name of a white semi-solid viscid rosin found on fir-trees; or an inferior sort of turpentine, poor in oil.

GALLATES; salts consisting of gallic acid combined with bases; the most important being that with oxyde of iron, constituting a principal part of the black dye.

GALLIC ACID is the peculiar acid extracted from gall-nuts; which see.

GALLIPOLI OIL is a coarse olive oil, containing more or less mucilage; imported from seaport so named, of the province of Otranto, in the kingdom of Naples.

GALL-NUTS, or GALLS, (*Noix de Galle*, Fr.; *Galläpfel*, Germ.;) are excrescences found upon the leaves and leaf-stalks of a species of oak, called *Quercus infectoria*, which grows in the Levant. They are produced in consequence of the puncture of the female of the gall wasp (Cynips folii quercus), made in order to deposite her eggs; round which the juice of the tree exudes, and dries in concentric portions. When the insect gets fully formed, it eats through the nut, and flies off.

The Levant galls are of two different appearances and qualities; the first are heavy compact, imperforated, the insect not having been sufficiently advanced to eat its way through the shell; prickly on the surface; of a blackish or bluish green hue; about the size of a musket-ball. These are called *black*, blue, or Aleppo galls. The second are light, spongy, pierced with one or more holes; smooth upon the surface, of a pale grayish or reddish yellow color, generally larger than the first, and are called *white* galls. Besides the galls of the Levant, others come from Dalmatia, Illyria, Calabria, &c.; but they are of inferior quality, being found upon the *Quercus Cerris;* they are smaller, of a brownish color, and of inferior value. The further south the galls are grown, they are reckoned the better.

Galls consist principally of three substances; tannin or tannic acid; yellow extractive; and gallic acid. Their decoction has a very astringent and unpleasant bitter taste. The following are their habitudes with various reagents:—

Litmus paper is powerfully reddened.

Stannous chloride (*protomuriate of tin*) produces an isabel yellow precipitate.

Alum; a yellowish gray precipitate.

Acetate of lead; a thick yellowish white precipitate.

Acetate of copper; a chocolate brown precipitate.

Ferric sulphate (red sulphate of iron); a blue precipitate.

Sulphuric acid; a dirty yellowish precipitate.

Acetic acid brightens the muddy decoction.

The galls of the *Quercus Cerris* and common oak (*Galles à l'épine*, Fr.; *Knoppern*, Germ.) are of a dark brown color, prickly on the surface, and irregular in shape and size. They are used chiefly for tanning in Hungary, Dalmatia, and the southern provinces of the Austrian states, where they abound.

Tannin or tannic acid is prepared as follows: Into a long narrow glass adopter tube, shut at its lower orifice with a cotton wick, a quantity of pounded galls are put, and slightly pressed down. The tapering end of the tube being inserted into a matrass or bottle, the vacant upper half of the tube is filled with sulphuric ether, and then closed with a ground-glass stopper. Next day there will be found in the bottle a liquid in two distinct strata; of which the more limpid occupies the upper part, and the other, of a sirupy consistence and amber color, the lower. More ether must be filtered through the galls, till the thicker liquid ceases to augment. Both are now poured into a funnel, closed with the finger, and after the dense liquor is settled at the bottom, it is steadily run off into a capsule. This, after being washed repeatedly with ether, is to be transferred into a stove chamber, or placed under the receiver of an air pump, to be evaporated. The residuary matter swells up in a spongy crystalline form of considerable brilliancy, sometimes colorless, but more frequently of a faintly yellowish hue.

This is pure tannin, which exists in galls to the amount of from 40 to 45 per cent. It is indispensable that the ether employed in the preceding process be previously agitated with water, or that it contain some water, because by using anhydrous ether, not a particle of tannin will be obtained.

Tannic acid is a white or yellowish solid, inodorous, extremely astringent, very soluble in water and alcohol, much less so in sulphuric ether, and uncrystallizable. Its watery solution, out of contact of air, undergoes no change; but if, in a very dilute state, it be left exposed to the atmosphere, it loses gradually its transparency, and lets fall a slightly grayish crystalline matter, consisting almost entirely of gallic acid. For procuring this acid in a perfectly pure state, it is merely necessary to treat that solution thus changed with animal charcoal, and to filter it, in a boiling state, through paper previously washed with dilute muriatic acid. The gallic acid will fall down in crystals as the liquid cools.

If the preceding experiment be made in a graduated glass tube containing oxygen over mercury, this gas will be absorbed, and a corresponding volume of carbonic acid gas will be disengaged. In this case the liquor will appear in the course of a few weeks as if traversed with numerous crystalline colorless needles of gallic acid.

Tannin or tannic acid consists of carbon 51·56; hydrogen 4·20; oxygen 44·24.

From the above facts it is obvious that gallic acid does not exist ready formed in gall-nuts, but that it is produced by the reaction of atmospheric oxygen upon the tannin of these concretions.

Gallic acid is a solid, feebly acidulous and styptic to the taste, inodorous, crystallizing in silky needles of the greatest whiteness; soluble in about 100 times its weight of cold, and in a much smaller quantity of boiling water; more soluble in alcohol than in water, but little so in sulphuric ether.

Gallic acid does not decompose the salts of protoxyde of iron, but it forms, with the sulphate of the peroxyde, a dark blue precipitate, much less insoluble than the tannate of iron. Gallic acid takes the oxyde from the acetate and nitrate of lead, and throws down a white gallate unchangeable in the air, when it is mixed with that acetate and nitrate. It occasions no precipitate in solutions of gelatine (isinglass or glue), by which criterion its freedom from tannin is verified.

Gallic acid occurs but seldom in nature; and always united to brucine, veratrine, or lime. Its constituents are carbon 49·89; hydrogen 3·49; oxygen 46·62. In the crystalline state it contains one atom of water, which it loses by drying.

Scheele obtained gallic acid by infusing pounded galls for 3 or 4 days in 8 times their weight of water, and exposing the infusion to the air, in a vessel covered loosely with paper. At the end of two months, the liquor had almost all evaporated, leaving some mouldiness mixed with a crystalline precipitate. The former being removed, the deposite was squeezed in a linen cloth, and then treated with boiling water. The solution, being gradually evaporated, yielded crystals of gallic acid, granular or star-like, of a grayish color. These crystals might be whitened by boiling their solution along with a little animal charcoal. About one fifth of gallic acid may be obtained by Scheele's process from good gall-nuts.

From a decoction of 500 parts of galls, Sir H. Davy obtained 185 parts of solid extract; which consisted of 130 parts of tannin; 31 parts of gallic acid with extractive; 13 parts of mucilage; 12 parts of lime and salts. Hence gall-nuts would seem to contain, by this statement, more than two thirds of their weight of tannin. This result is now seen, from the above experiments of Pelouze, to have been incorrect, in consequence of the admixture of yellow extractive in Davy's tannin.

The use of galls in many processes of dyeing, and in making black ink, is detailed under their respective heads.

GALL OF ANIMALS, or OX-GALL, *purification of.* Painters in water colors, scourers of clothes, and many others, employ ox-gall or bile; but when it is not purified, it is apt to do harm from the greenness of its own tint. It becomes therefore an important object to clarify it, and to make it limpid and transparent like water. The following process has been given for that purpose. Take the gall of newly killed oxen, and after having allowed it to settle for 12 or 15 hours in a basin, pour the supernatant liquor off the sediment into an evaporating dish of stone ware, and expose it to a boiling heat in a water bath, till it is somewhat thick. Then spread it upon a dish, and place it before a fire till it becomes nearly dry. In this state it may be kept for years in jelly pots covered with paper, without undergoing any alteration. When it is to be used, a piece of it of the size of a pea is to be dissolved in a table spoonful of water.

Another and probably a better mode of purifying ox-gall is the following. To a pint of the gall boiled and skimmed, add one ounce of fine alum in powder, and leave the mixture on the fire till the alum be dissolved. When cooled, pour into a bottle, which is to be loosely corked. Now take a like quantity of gall, also boiled and skimmed, add an ounce of common salt to it, and dissolve with heat; put it when cold into a bottle, which is likewise to be loosely corked. Either of these preparations may be kept for several years without their emitting a bad smell. After remaining three months, at a moderate temperature, they deposite a thick sediment, and become clearer, and fit for ordinary uses, but not for artists in water colors and miniatures, on account of their yellowish-green color. To obviate this inconvenience, each of the above liquors is to be decanted apart, after they have become perfectly settled, and the clear portion of both mixed together in equal parts. The yellow coloring matter still retained by the mixture coagulates immediately and precipitates, leaving the ox-gall perfectly purified and colorless. If wished to be still finer, it may be passed through filtering paper; but it becomes clearer with age, and never acquires a disagreeable smell, nor loses any of its good qualities.

Clarified ox-gall combines readily with coloring matters or pigments, and gives them solidity either by being mixed with or passed over them upon paper. It increases the brilliancy and the durability of ultramarine, carmine, green, and in general of all delicate colors, whilst it contributes to make them spread more evenly upon the paper, ivory, &c. When mixed with gum-arabic, it thickens the colors without communicating to them a disagreeable glistering appearance; it prevents the gum from cracking, and fixes the colors so well that others may be applied over them without degradation. Along with lamp black and gum, it forms a good imitation of China ink. When a coat of ox-gall is put upon drawings made with black lead or crayons, the lines can no longer be effaced, but may be painted over safely with a variety of colors previously mixed up with the same ox-gall.

Miniature painters find a great advantage in employing it; by passing it over ivory, it removes completely the unctuous matter from its surface; and when ground with the colors, it makes them spread with the greatest ease, and renders them fast.

It serves also for transparencies. It is first passed over the varnished or oiled paper and is allowed to dry. The colors mixed with the gall are then applied, and canno. afterwards be removed by any means.

It is adapted finally for taking out spots of grease and oil

GALL OF GLASS, called also sandiver, is the neutral salt skimmed off the surface of melted crown glass; which, if allowed to remain too long, is apt to be reabsorbed in part, and to injure the quality of the *metal*, as the workmen call it.

GALVANIZED IRON, is the somewhat fantastic name newly given in France to iron tinned by a peculiar patent process, whereby it resists the rusting influence of damp air, and even moisture, much longer than ordinary tin plate. The following is the prescribed process. Clean the surface of the iron perfectly by the joint action of dilute acid and friction, plunge it into a bath of melted zinc, covered with sal-ammoniac, and stir it about till it be alloyed superficially with this metal; when the metal thus prepared is exposed to humidity, the zinc is said to oxidise slowly by a galvanic action, and to protect the iron from rusting within it, whereby the outer surface remains for a long period perfectly white, in circumstances under which iron tinned in the usual way would have been superficially browned and corroded with rust.

GALVANO-PLASTIC is the German name of *Electro-Metallurgy.*

GAMBOGE; (*Gomme Gutte*, Fr.; *Gutti*, Germ.) is a gum resin, concreted in the air, from the milky juice which exudes from several trees. The *gambogia gutta*, a tree which grows wild upon the coasts of Ceylon and Malabar, produces the coarsest kind of gamboge; the *guttœfera vera* (*Stalagmites cambogioides*) of Ceylon and Siam affords the best. It comes to us in cylindrical lumps, which are outwardly brown yellow, but reddish yellow within, as also in cakes; it is opaque, easily reducible to powder of specific gravity 1·207, scentless, and nearly devoid of taste, but leaves an acrid feeling in the throat. Its powder and watery emulsion are yellow. It consists of 80 parts of a hyacinth red resin, soluble in alcohol; and 20 parts of gum; but by another analysis, of 89 of resin, and 10·5 of gum. Gamboge is used as a pigment, and in miniature painting, to tinge gold varnish; in medicine as a powerful purge. It should never be employed by confectioners to colour their *liqueurs*, as they sometimes do.

GANGUE. A word derived from the German *gang*, a vein or channel. It signifies the mineral substance which either encloses or usually accompanies any metallic ore in the vein. Quartz, lamellar carbonate of lime, sulphate of baryta, sulphate and fluate of lime, generally form the gangues; but a great many other substances become such when they predominate in a vein. In metallurgic works the first thing is to break the mixed ore into small pieces, in order to separate the valuable from the useless parts, by processes called stamping, picking, sorting. See METALLURGY and MINES.

GARANCINE, is a dyeing substance prepared from madder, called in the French language *garance.*

A patent was granted in August, 1843, to Mr. F. Steiner, for the manufacture of *Garancine* from used madder, formerly thrown away, as being exhausted of its dyeing principle. His process is as follows:—"A large filter is constructed outside the building in which the dye-vessels are situated, formed by sinking a hole in the ground, and lining it at the bottom and sides with bricks without any mortar to unite them. A quantity of stones or gravel is placed upon the bricks, and over the stones or gravel common wrappering, such as is used for sacks. Below the bricks is a drain to take off the water which passes through the filter. In a tub adjoining the filter is kept a quantity of dilute sulphuric acid, of about the specific gravity of 105, water being 100. Hydrochloric acid will answer the several purposes, but sulphuric acid is preferred as more economical. A channel is made from the dye-vessels to the filter. The madder which has been employed in dyeing is run from the dye-vessels to the filter; and while it is so running, such a portion of the dilute sulphuric acid is run in and mixed with it as changes the colour of the solution and the undissolved madder to an orange tint or hue. This acid precipitates the colouring matter which is held in solution, and prevents the undissolved madder from fermenting or otherwise decomposing. When the water has drained from the madder through the filter, the residuum is taken from off the filter and put into bags. The bags are then placed in an hydraulic press, to have as much water as possible expressed from their contents. In order to break the lumps which have been formed by compression, the madder or residuum is passed through a sieve. To 5 cwt. of madder in this state, placed in a wood or lead cistern, 1 cwt. of sulphuric acid of commerce is sprinkled on the madder through a lead vessel similar in form to the ordinary watering-can used by gardeners. An instrument like a garden spade or rake is next used, to work the madder about, so as to mix it intimately with the acid. In this stage the madder is placed upon a perforated lead plate, which is fixed about five or six inches above the bottom of a vessel. Between this plate and the bottom of the vessel is introduced a current of steam by a pipe, so that it passes through the perforated plate and the madder which is upon it. During this process, which occupies from one to two hours, a substance is produced of a dark brown colour approaching to black. This substance is garancine and insoluble carbonized matter. When cool, it is placed upon a filter and washed with clear cold water until the water passes from it without an acid taste. It is then put into bags and pressed with an hydraulic press. The substance is dried in a stove and ground to a fine powder under ordinary madder stones, and afterwards passed through a sieve. In order to neutralize any acid that may remain, from 4 to 5 lbs. of dry carbonate of soda for every hundred weight of this substance is added and intimately mixed. The garancine in this state is ready for use."

GARNET (*Grenat*, Fr.; *Granat*, Germ.); is a vitreous mineral of the cubic system, of which the predominating forms are the rhomboidal dodecahedron and the trapæzohedron; specific gravity varying from 3·35 to 4·24; fusible at the blowpipe. Its constituents are, silica, 42; alumina, 20·0; lime, 34·0; protoxide of iron, 4. Garnets are usually disseminated, and occur in all the primitive strata from gneiss to clay slate. The finer varieties, noble garnet or Almandine, and the reddish varieties of Grossulaire (Essonite), are employed in jewelry; the first are called the Syrian or oriental; the others, hyacinth. In some parts of Germany garnets are so abundant as to be used as fluxes to some iron ores: in others, the garnet gravel is washed, pounded, and employed as a substitute for emery. The garnets of Pegu are most highly valued. Factitious garnets may be made by the following composition:—Purest white glass, 2 ounces; glass of antimony, 1 ounce; powder of cassius, 1 grain; manganese, 1 grain.

GAULTHERIA OIL; an aromatic oil, called in commerce wintergreen oil. It is obtained from a shrub of the *Ericeen* family, (*Gaultheria procumbens* L., *Canadian tea.*) The oil occurs in all parts of the plant, but mostly in the flowers, and may be extracted by alcohol, but not by water from the dried or scentless plant. The same oil is obtained from the bark of sweet birch, by distilling it with water, whereby it results from the mutual action of a body like emulsion upon a body like amygdalin. The oil is colourless, but becomes reddish in the air, as it is found in commerce. Its specific gravity is 1·173, and its boiling point 211° C.; it distils at the constant heat of 220°; it has then a gravity 1·18: the watery solution of the oil produces with the red salts of iron a violet tint, which becomes with excess of oil very deep and rich. Its constituents are

$$\begin{array}{rcrr} C_{16} & = & 1200 & 63{\cdot}16 \\ H_8 & = & 100 & 5{\cdot}26 \\ O_6 & = & 600 & 31{\cdot}58 \\ \hline & & 1900 & 100{\cdot}00 \end{array}$$

If we distil the oil with an excess of caustic potash, wood spirit comes over, and the remainder consists of salicylate of potash. The oil is a natural compound wood ether, which may be prepared artificially by distilling together two parts of salicylic acid with two parts of dry wood spirit, and one part of oil of vitriol. The ether is separable from the distilled liquor by means of chlorcalcium. Bromine and chlorine act violently upon the oil. The gaultheria oil combines without decomposition into a peculiar class of salts.

GAULTHERINE. When the pulverized dried bark of *betula lenta* is exhausted with cold alcohol of 95°, it can afford no more oil. The fluid which contains the gaultherine has a slight bitterish taste, and by evaporation it forms a dry gummy mass which at a high heat leaves a coaly residual.

Oil of vitriol dissolves the gaultherine with a red colour and a flavour of the oil.

GAS (Eng. and Fr.; *Gaz*, Germ.) is the generic name of all those elastic fluids which are permanent under a considerable pressure, and at the temperature of zero of Fahrenheit. In many of them, however, by the joint influence of excessive cold and pressure, the repulsive state of the particles may be balanced or subverted, so as to transform the elastic gas into a liquid or a solid. For this most interesting discovery, we are indebted to the fine genius of Mr. Faraday.

The following table exhibits the temperatures and pressures at which certain gases are liquefied.

Name of the gas.	Becomes liquid		Calculated boiling point; Barom. = 30 inches.
	At	Under a pressure of	
Sulphurous acid - -	59° F.	3 atmospheres.	— 4° Fahr.
Chlorine . - -	60	4	— 22
Ammonia - - -	50	6·5	— 64
Sulphureted hydrogen - -	50	17	— 142
Carbonic acid - - -	32	36	— 229
Hydrochloric or muriatic acid -	50	50	— 249
Deutoxide of azote - -	45	50	— 254

Liquid carbonic acid becomes solidified, into a snowy-looking substance, by its own rapid evaporation. Oxygen, hydrogen, and azote, have hitherto resisted all attempts to divest them of their elastic form. For this purpose, it is probable that a condensing force equal to that of 650 atmospheres, will be required.

The volume of any gas is, generally speaking, inversely as the pressure to which it is exposed; thus, under a double pressure its bulk becomes one half; under a triple pressure, one third; and so on. For the change of volume in gaseous bodies by heat, see Expansion.

Ammonia, carbonic acid, carbureted hydrogen, chlorine, muriatic acid, sulphurous acid, sulphureted hydrogen, are the gases of most direct interest in the arts and manufactures. Their detailed examination belongs to a work on chemistry.

GAS-LIGHT. (*Eclairage par gas*, Fr.; *Gaslicht*, Germ.) Dr. Clayton demonstrated, by numerous experiments in 1737 and 1738, that bituminous pit-coal subjected to a red heat in close vessels, afforded a great deal of an air similar to the fire-damp of mines, but which burned with a brighter flame. It does not appear that this species of factitious air was ever produced from pit-coal for the purpose of artificial illumination till 1792, when Mr. William Murdoch, engineer to Messrs. Bolton and Watt, employed coal gas for lighting his house and offices, at Redruth in Cornwall. The gas was generated in an iron retort, whence it was received in a gasometer, distributed in different situations by pipes, and finally burned at small apertures which could be opened and stopped at pleasure. He moreover made this light moveable, by confining the gas in portable tin-plate vessels, and burning it wherever he pleased. Between this period and 1802, Mr. Murdoch continued at intervals to make similar experiments; and upon occasion of the national illumination in the spring of the latter year, at the peace of Amiens, he lighted up part of the Soho manufactory with a public display of gas-lights.

The earliest application of this artificial light, on a large systematic scale, was made at Manchester; where an apparatus for lighting the great cotton mills of Messrs. Philips and Lee, was fitted up in 1804 and 1805, under the direction of Mr. Murdoch. A quantity of light, nearly equal to 3000 candles, was produced and distributed in this building. This splendid pattern has been since followed very generally in Great Britain, and more or less in many parts of the continents of Europe and America. By the year 1822, gas-lighting in London had become the business of many public companies. At the Peter street station, for example, 300 retorts had been erected, supplying 15 gasometers, having each an average capacity of 20·626 cubic feet, but, being never quite filled, their total contents in gas might be estimated at 309,385 cubic feet. The extent of main pipes of distribution belonging to this station was then about 57 miles, with two separate mains in some of the streets. The product of gas was from 10,000 to 12,000 cubic feet from a chaldron of coals. The annual consumption of coals was therefore altogether 9282 chaldrons, affording 11,384,000 cubic feet of gas, allowing 153 retorts to be in constant daily action, upon an average of the year; and illuminating 10,660 private lamps, 2248 street lamps, and 3894 theatre lamps.

At the Brick-lane works, 371 retorts were fixed in 1822, 133 being worked on an average of summer and winter. There were 12 gasometers, charged with an average quantity of gas amounting to 197,214 cubic feet. Of coals, 8060 chaldrons were annually consumed; 96,720,000 cubic feet of gas were generated; for the supply of 1978 public lamps, and 7366 private ones, connected with main pipes 40 miles long.

At the Curtain-road gas establishment, there were 240 retorts; but the greatest number worked in 1821 was only 80, and the lowest 21. The six gasometers had an average contents of 90,467 cubic feet. Of coals, 3336 chaldrons were annually consumed, yielding 40,040,000 cubic feet of gas, that supplied 3860 private lamps, and 629 public ones, by means of mains 25 miles long. The above three stations belonged to the London Gas-Light and Coke Company.

The City of London Gas-Light Company, Dorset street, had built up 230 retorts, and 6 gasometers, while two were preparing; having a total capacity of 181,282 cubic feet. Of private lamps 5423 were lighted, and 2413 public ones, from mains extending 50 miles. The quantity of coals carbonized amounted to 8840 chaldrons; producing 106,080,000 cubic feet of gas.

The South London Gas-Light and Coke Company had mounted at Bankside 143 retorts, with 3 gasometers; the contents of the whole being 41,110 cubic feet, connected with mains from 30 to 40 miles long. At their other station, in Wellington street, 9 large gasometers were then erecting, with a capacity of 73,565 cubic feet, which were to be supplied with gas from Bankside, till retorts were mounted for them.

The Imperial Gas-Light and Coke Company had at that time 6 gasometers in progress at their Hackney station.

In 1822 there were thus four great companies, having in all 47 gasometers at work, capable of containing 917,940 cubic feet of gas, supplied by 1315 retorts, which generated per annum upwards of 397,000,000 cubic feet of gas, by which 61,203 private lamps, and 7268 public or street lamps, were lighted in the metropolis. Besides these public companies, there were likewise several private ones.

1. *Of the generation of illuminating gases.*—Pure hydrogen gas burns with too feeble a flame to be employed for illumination. But carbureted hydrogen having the property of precipitating its carbon in the act of burning, its solid particles become incandescent. and diffuse a vivid light. The more carbon it contains, the more brightly does it burn This gas exists in two distinct states of combination. In the first, two measures of hydrogen gas are combined with one measure of the vapor of carbon, forming together one measure whose specific gravity is of course the sum of the weights of the constituents, or 0·559; atmospherical air being 1·000. This is the gas which is found in mines, and is also evolved in ditches from decomposing vegetable matter. In the second, two measures of hydrogen gas are combined with two of gaseous carbon, forming also one volume or measure whose weight or specific gravity is 0·985. This was at one time called the olefiant gas, because when mixed with chlorine an oily looking compound was produced. It may be called as well oil gas, because it is generated in considerable quantities by the igneous decomposition of oil. Thus the olefiant gas contains in the same volume double the quantity of carbon of common carbureted hydrogen, and it burns with a proportionably brighter flame. The gaseous oxyde of carbon, as well as sulphureted hydrogen gas, burns with a feeble blue light, but the latter produces in combustion sulphurous acid, an offensive and noxious gas.

By dry distillation or carbonization in close vessels, all bodies of vegetable and animal origin disengage carbureted hydrogen gas; even charcoal, when placed in ignition in contact with steam, by decomposing the water, produces abundance of carbonic acid, carbureted hydrogen, hydrogen, and carbonic oxyde. After separating the carbonic acid with lime water, that mixed gas contains in 100 measures, 20 of carbureted hydrogen; the rest being hydrogen and carbonic oxyde, so that the gaseous mixture cannot be used for illumination. The best substances for furnishing a gas rich in luminiferous materials are, pitcoal, especially the cannel coal, resin, oil, fats of all kinds, tar, wax, &c. In some cases the gases evolved during the igneous decomposition of bones and other animal matters for the production of ammonia, may be employed for procuring light, but they are apt to emit a fetid odor.

When coals are heated in a cast-iron retort to ignition, the progress of decomposition is as follows. First, and before the retort becomes red hot, steam issues along with the atmospheric air. When the retort begins to redden, tar distils in considerable quantity with some combustible gas, of which hydrogen mixed with ammoniacal gas forms a part. The evolution of gas increases as the retort becomes hotter, with a continual production of tar and ammoniacal liquor as well as sulphurous acid from the pyrites of the coal, which unites with the ammonia. When the retort has come to a bright cherry red heat, the disengagement of gas is most active. By and by the gaseous production diminishes, and eventually ceases entirely, although the heat be increased. In the retort a quantity of carbonized coal or coke remains, while tar is found at the bottom of the receiver, covered with the ammoniacal liquor, and combined with carbonic and sulphurous acids, and sulphureted hydrogen.

If, during this distillation, the combustible gas be collected and examined at the several stages of the process, it is found to differ extremely in its luminiferous powers. That which comes off before the retort has acquired its proper temperature, gives a feeble light, and resembles the gas obtained by the ignition of moist charcoal, consisting chiefly of hydrogen. That evolved when the retort has just acquired throughout a vivid red heat, is the best of all, consisting chiefly of bi-carbureted hydrogen or olefiant gas. From good coal, it consists, for example, in 100 measures, of 13 of olefiant gas, 82·5 of carbureted hydrogen, 3·2 carbonic oxyde, 1·3 azote; the mixture having a specific gravity of 0·650. At a later period, as after 5 hours, it contains 7 measures of olefiant gas, 56 of carbureted hydrogen, 11 of carbonic oxyde, 21·3 of hydrogen, 4·7 of azote; the specific gravity of the whole being 0·500. Towards the end of the operation, as after 10 hours, it contains twenty measures of carbureted hydrogen, 10 of carbonic oxyde, 60 of hydrogen, 10 of azote, with a specific gravity of only 0·345. The hydrogen becomes sulphureted hydrogen, if there be much pyritous matter in the coal. The larger proportion of the gas is disengaged during the first hour, amounting to about one fifth of the whole; in the three following hours the disengagement is tolerably uniform, constituting in all fifty-four hundredths; in the sixth hour, it is one tenth; in the seventh and eighth hours sixteen hundredths.

From these observations are derived the rules for the production of a good light gas from coals. They show that the distillation should commence with a retort previously heated to a cherry red, since thereby good gas is immediately produced, and a portion of the tar is also converted into gas, instead of being simply distilled over into the condenser pit; that this heat should be steadily continued during the whole operation, from 5 to 8 hours; that it should not be increased, especially towards the end, for fear of generating carbonic oxyde and hydrogen gases, as well as of injuring the retort when the cooling agency of gasefication has become feeble; and that the operation should be stopped some time before gas ceases to come over, lest gases with feeble illuminating power should impoverish the contents of the gasometer. Upon the average, a pound of good coal affords four cubic feet of gas, or a chaldron=26 cwts. London measure, affords from 12,000 to 15,000 cubic feet, according to the form of the retort, and the manner of firing it.

When oil, fats, rosin, tar, &c. are employed for the production of a light gas, it is not sufficient to introduce these substances into the retorts, and to heat them, as is done with coals. In this case, the greater part of them would distil over in the state of volatile oils, and very little gas be generated, only as much as corresponded to the quantity of fat, &c. in immediate contact with the retort. It becomes therefore necessary to fill the retorts with pieces of brick or coke; and to keep them in ignition, while the oil, &c. is slowly introduced into their interior. The fats instantly assume the vaporous state, and thus coming into contact upon an extensive surface with the ignited bricks, are decomposed into combustible gases. A small portion of carbonaceous matter remains in the retort, while much olefiant gas is formed, possessing a superior illuminating power to common coal gas, and entirely free from sulphureous impregnation. The best oil gas is generated at a dull red, a heat much below what is requisite for the decomposition of coal. A more intense heat would indeed produce a greater volume of gas, but of a poorer quality, because the olefiant gas thereby deposites one half of its carbon, and is converted into common carbureted hydrogen. Oil affords at a lively red heat, gases which contain in 100 measures, 19 of olefiant gas, 32·4 of carbureted hydrogen, 12·2 of carbonic oxyde gas, 32·4 of hydrogen, and 4 of azote; the mean specific gravity being only 0·590. At a more moderate temperature it yields 22·5 of the olefiant, 50·3 carbureted hydrogen, 15·5 carbonic oxyde, 7·7 hydrogen, and 4 azote, with a specific gravity of 0·758. It contains when generated by dull ignition, as is usual in works on the manufacturing scale, in 100 parts from 38 to 40 of olefiant gas, and besides the carbureted hydrogen, a few per cent. of carbonic oxyde and azote, with a specific gravity of 0·900, and even upwards. One pound of oil or fluid fat affords 15 cubic feet of gas; of tar affords about 12 cubic feet; of rosin or pitch, 10 cubic feet.

When the oil gas is compressed by a force of from 15 to 20 atmospheres, as was the practice of the Portable Gas Company, about one fifth of the volume of the gas becomes liquefied into an oily, very volatile fluid, having the specific gravity 0·821. It is a mixture of three fluids (consisting of carbureted hydrogen), of different degrees of volatility. The most volatile of these boils even under 32° F. Some of the vapor of this gas-oil is mixed with the olefiant gas in the general products of decomposition; in consequence of which they are sometimes richer in carbon than even olefiant gas, and have a higher illuminating power. Oil gas contains about 22 per cent. and coal gas about 3¼ per cent. of this oily vapor. In the estimations of the composition of the gases given above, this vapor is included under olefiant gas. This vapor combines readily with sulphuric acid, and is thus precipitated from the gaseous mixture. The amount of olefiant gas is shown, by adding to the gas, contained over water, one half of its volume of chlorine, which, in the course of an hour or two, condenses the olefiant gas into an oily looking liquid (chloride of hydrocarbon.) After the mixture, the gases must be screened from the light, otherwise the common carbureted hydrogen would also combine with the chlorine, while water and carbonic acid would make their appearance.

The oil employed for affording gas is the crudest and cheapest that can be bought; even the blubber and sediment of whale oil are employed with advantage. After all, however, coal is so much cheaper, and the gas produced from it is now so well purified, that oil and rosin are very little used in gas apparatus.

Apparatus for Coal Gas.—Coal gas, as it issues from the retort, cannot be directly employed for illumination; for it contains vapors of tar and coal oil, as also steam impregnated with the carbonate, sulphite, and hydrosulphuret of ammonia. These vapors would readily condense in the pipes through which the gas must be distributed, and would produce obstructions; they must therefore be so far removed by previous cooling, as to be liable to occasion no troublesome condensation at ordinary temperatures. The crude coal gas contains moreover sulphureted hydrogen, whose combustion for light would exhale an offensive sulphureous odor, that ought to be got rid of as much as possible. Carbonic acid and carbonic oxyde gases, generated at first from the decomposition of the steam by the ignited coal, enfeeble the illuminating power of the gas, and should be removed. The disengagement of gas in the retorts is never uniform, but varies with the degree of heat to which they are exposed; for which reason the gas must be received in a gasometer, where it may experience uniform pressure, and be discharged uniformly into the pipes of distribution, in order to ensure a steady discharge of gas, and uniform intensity of light in the burners. A coal gas apparatus ought therefore to be so constructed as not only to generate the gas itself, but to fulfil the above conditions.

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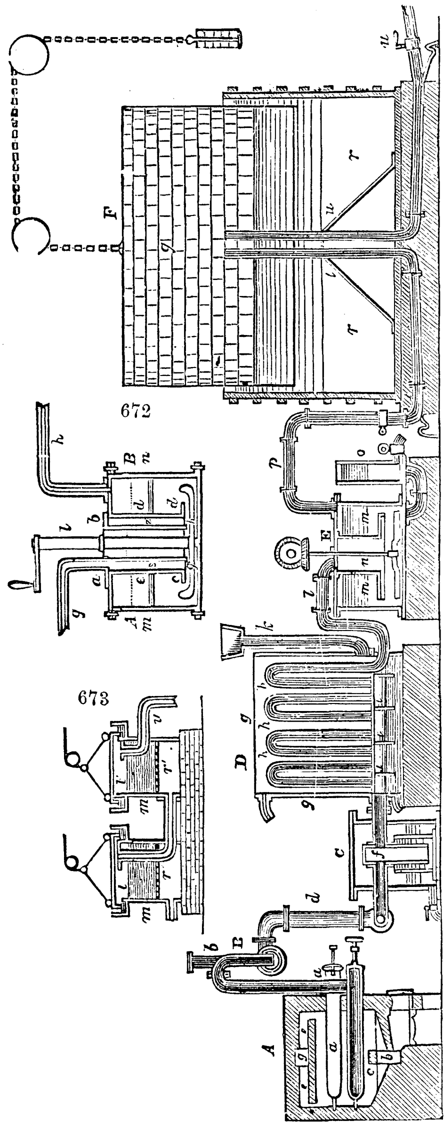
In *fig.* 669, such an apparatus is represented, where the various parts are shown connected with each other, in section.

A is the furnace with its set of cylindrical or elliptical retorts, five in number. From each of these retorts, a tube *b* proceeds perpendicularly upwards, and then by a curved or saddle-tube, it turns downwards, where it enters a long horizontal cylinder under B, shut at each end with a screw cap, and descends to beneath its middle, so as to dip about an inch into the water contained in it. From one end of this cylinder the tube *d* passes downward, to connect itself with a horizontal tube which enters into the *tar pit* or *cistern* C, by means of the vertical branch *f*. This branch reaches to near the bottom of the cylindrical vessel, which sits on the sole of the tar cistern. From the other side of the vertical branch *f*, the main pipe proceeds to the condenser D, and thence by the pipe *l*, into the purifier E; from which the gas is immediately transmitted by the pipe *p* into the gasometer F.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The operation proceeds in the following way:—As soon as gas begins to be disengaged from the ignited retort, tar and ammoniacal liquor are deposited in the cylindrical receiver B, and fill it up till the superfluity runs over by the pipe *d*, the level being constantly preserved at the line shown in the figure. By the same tarry liquid, the orifices of the several pipes *b*, issuing from the retorts, are closed; whereby the gas in the pipe *d* has its communication cut off with the gas in the retorts. Hence if one of the retorts be opened and emptied, it remains shut off from the rest of the apparatus. This insulation of the several retorts is the function of the pipe under B, and therefore the recurved tube *b* must be dipped as far under the surface of the tarry liquid, as to be in equilibrio with the pressure of the gas upon the water in the purifier. The tube *b* is closed at top with a screw cap, which can be taken off at pleasure, to permit the interior to be cleansed.

Both by the overflow from the receiver-pipe B, and by subsequent condensation in the tube *d*, tar and ammoniacal liquor collect progressively in the cistern or pit under C, by which mingled liquids the lower orifice of the vertical tube *f* is closed, so that the gas cannot escape into the empty space of this cistern. These liquids flow over the edges of the inner vessel when it is full, and may from time to time be drawn off by the stopcock at the bottom of the cistern.

Though the gas has, in its progress hitherto, deposited a good deal of its tarry and ammoniacal vapors, yet, in consequence of its high temperature, it still retains a considerable portion of them, which must be immediately abstracted, otherwise the tar would pollute the lime in the vessel E, and interfere with its purification. On this account the gas should, at this period of the process, be cooled as much as possible, in order to condense these vapors, and to favor the action of the lime in the purifier E, upon the sulphureted hydrogen, which is more energetic the lower the temperature of the gas. The coal gas passes, therefore, from the tube *f* into the tube *h* of the condenser D, which is placed in an iron chest *g* filled with water, and it deposites more tar and ammoniacal liquor in the under part of the cistern at *t*, *t*. When these liquids have risen to a certain level, they overflow into the tar-pit, as shown in the figure, to be drawn off by the stop cock as occasion may require.

The refrigerated gas is now conducted into the purifier E, which is filled with milk of lime, made by mixing one part of slaked lime with 25 parts of water. The gas, as it enters by the pipe *l*, depresses the water in the wide cylinder *n*, thence passes under the perforated disc in the under part of that cylinder, and rising up through innumerable small holes, is distributed throughout the lime liquid in the vessel *m*. By contact with the lime on this extended surface, the gas is stripped of its sulphureted hydrogen and carbonic acid, which are condensed into the hydro-sulphuret and carbonate of lime; it now enters the gasometer F in a purified state, through the pipe *p t*, and occupies the space *q*. The gasometer, pressing with a small unbalanced force over the counterweight *s*, expels it through the main *u u*, in communication with the pipes of distribution through the buildings or streets to be illuminated.

The parts A B C D E and F, of which this apparatus consists, are essential constituents of every good coal-gas work. Their construction rests upon peculiar principles, is susceptible of certain modifications, and therefore deserves to be considered in detail.

The Retorts. — These are generally made of cast iron, though they have occasionally been made of baked clay, like common earthenware retorts. The original form was a cylinder, which was changed to an ellipse, with the long axis in a horizontal direction, then into the shape of the letter D with the straight line undermost, and lastly into a semi-cylinder, with its horizontal diameter 22 inches, and its vertical varying from 9 to 12. The kidney form was at one time preferred, but it has been little used of late.

The form of retort represented in *fig.* 670 has been found to yield the largest quantity of good gas in the shortest time, and with the least quantity of firing. The length is 7½, and the transverse area, from one foot to a foot and a half square. The arrows show the direction of the flame and draught in this excellent bench of retorts, as mounted by Messrs. Barlow.

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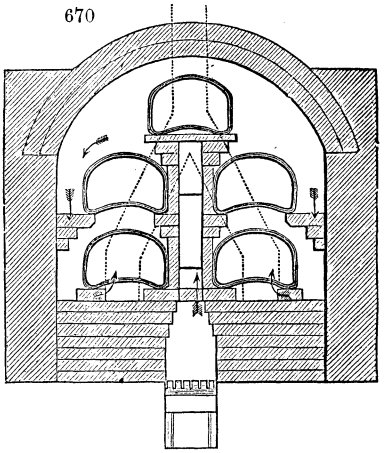

The charge of coals is most conveniently introduced in a tray of sheet iron, made somewhat like a grocer's scoop, adapted to the size of the retort, which is pushed home to its further end, inverted so as to turn out the contents, and then immediately withdrawn.

The duration of the process, or the time of completing a distillation, depends upon the nature of the coal and the form of the retort. With cylindrical retorts it cannot be finished in less than 6 hours, but with elliptical and semi-cylindrical retorts, it may be completed in 4 or 5 hours. If the distillation be continued in the former for 8 hours, and in the latter for 6, gas will continue to be obtained, but during the latter period of the operation, of indifferent quality.

The Receiver. — If the furnace contains only 2 or 3 retorts, a simple cylindrical vessel standing on the ground half filled with water, may serve as a receiver; into which the tube from the retort may be plunged. It should be provided with an overflow pipe for the tar and ammoniacal liquor. For a range of several retorts, a long horizontal cylinder is preferable, like that represented at B in *fig.* 671. Its diameter is from 10 to 15 inches. This cylinder may be so constructed as to separate the tar from the ammoniacal liquor, by means of a syphon attached to one of its ends.

The Condenser.— The condenser, represented in *fig.* 669, consists of a square chest *g*, made of wrought iron plates open at top, but having its bottom pierced with a row of holes, to receive a series of tubes. To these holes the upright four-inch tubes *h h* are secured by flanges and screws, and they are connected in pairs at top by the curved or saddle tubes. The said bottom forms the cover of the chest *t*, *t*, which is divided by vertical iron partitions, into half as many compartments as there are tubes.

These partition plates are left open at bottom, so as to place the liquids of each compartment in communication. Thereby the gas passes up and down the series of tubes, in proceeding from one compartment to another. The condensed liquids descend into the box *t*, *t*, and flow over into the tar cistern, when they rise above the level *t*, *t*. The tar may be drawn off from time to time by the stopcock. Through the tube *k*, cold water flows into the condenser chest, and the warm water passes away by a pipe at its upper edge.

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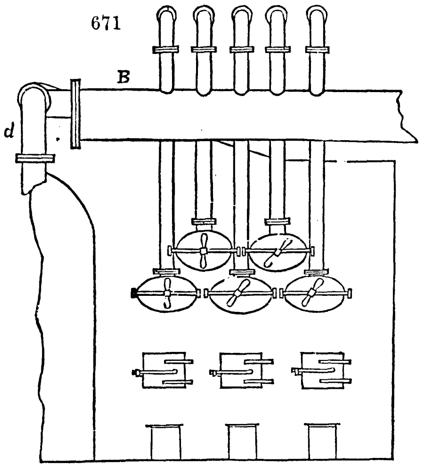

The extent of surface which the gas requires for its refrigeration before it is admitted into the washing-lime apparatus, depends upon the temperature of the milk of lime, and the quantity of gas generated in a certain time.

It may be assumed as a determination sufficiently exact, that 10 square feet of surface of the condenser can cool a cubic foot of gas per minute to the temperature of the cooling water. For example, suppose a furnace or arch with 5 retorts of 150 pounds of coal each, to produce in 5 hours 3000 cubic feet of gas, or 10 cubic feet per minute, there would be required, for the cooling surface of the condenser, 100 square feet = 10 × 10. Suppose 100,000 cubic feet of gas to be produced in 24 hours, for which 8 or 9 such arches must be employed, the condensing surface must contain from 800 to 900 square feet.

The Purifier.—The apparatus represented in the preceding figure is composed of a cylindrical iron vessel, with an air-tight cover screwed upon it, through which the cylinder *n* is also fixed air-tight. The bottom of this cylinder spreads out like the brim of a hat, forming a horizontal circular partition, which is pierced with holes. Through a stuffing box, in the cover of this interior cylinder, the vertical axis of the agitator passes, which is turned by wheel and pinion work, in order to stir up the lime from the bottom of the water in the purifier. The vessel *o* serves for introducing fresh milk of lime, as also for letting it off by a stopcock when it has become too foul for further use.

The quantity of lime should be proportioned to the quantity of sulphureted hydrogen and carbonic acid contained in the gas. Supposing that in good coal gas there is 5 per cent. of these gases, about one pound and a half of lime will be requisite for every hundred cubic feet of coal gas generated, which amounts to nearly one sixteenth of the weight of coal subjected to decomposition. This quantity of lime mixed with the proper quantity of water will form about a cubic foot of milk of lime. Consequently, the capacity of the purifier, that is, of the interior space filled with liquid, may be taken at four sevenths of a cubic foot for every hundred cubic feet of gas passing through it in one operation; or for 175 cubic feet of gas, one cubic foot of liquor. After every operation, that is, after every five or six hours, the purifier must be filled afresh. Suppose that in the course of one operation 20,000 cubic feet of gas pass through the machine, this should be able to contain $\frac{20,000}{175} = 114$ cubic feet of milk of lime; whence its diameter should be seven feet, and the height of the liquid three feet. If the capacity of the vessel be less, the lime milk must be more frequently changed.

In some of the large gas works of London the purifier has the following construction, whereby an uninterrupted influx and efflux of milk of lime takes place. Three single purifiers are so connected together, that the second vessel stands higher than the first, and the third than the second; so that the discharge tube of the superior vessel, placed somewhat below its cover, enters into the upper part of the next lower vessel; consequently, should the milk of lime in the third and uppermost vessel rise above its ordinary level, it will flow over into the second, and thence in the same way into the first; from which it is let off by the eduction pipe. A tube introduces the gas from the condenser into the first vessel, another tube does the same thing for the second vessel, &c., and the tube of the third vessel conducts the gas into the gasometer. Into the third vessel, milk of lime is constantly made to flow from a cistern upon a higher level. By this arrangement, the gas passing through the several vessels in proportion as it is purified, comes progressively into contact with purer milk of lime, whereby its purification becomes more complete. The agitator *c*, provided with two stirring paddles, is kept in continual rotation. The pressure which the gas has here to overcome is naturally three times as great as with a single purifier of like depth.

Fig. 672 is a simple form of purifier, which has been found to answer well in practice. Through the cover of the vessel A B, the wide cylinder *e d* is inserted, having its lower end pierced with numerous holes. Concentric with that cylinder is the narrower one *s z*, bound above with the flange *a b*, but open at top and bottom. The under edge *g h* of this cylinder descends a few inches below the end *c d* of the outer one. About the middle of the vessel the perforated shelf *m n* is placed. The shaft of the agitator *l*, passes through a stuffing box upon the top of the vessel. The gas-pipe *g*, proceeding from the condenser, enters through the flange *a b* in the outer cylinder, while the gas-pipe *h* goes from the cover to the gasometer. A stopcock upon the side, whose orifice of discharge is somewhat higher than the under edge of the outer cylinder, serves to draw off the milk of lime. As the gas enters through the pipe *g* into the space between the two cylinders, it displaces the liquor till it arrives at the holes in the under edge of the outer cylinder, through which, as well as under the edge, it flows, and then passes up through the apertures of the shelf *m n* into the milk of lime chamber; the level of which is shown by the dotted line. The stirrer, *l*, should be turned by wheel work, though it is here shown as put in motion by a winch handle.

In order to judge of the degree of purity of the gas after its transmission through the lime machine, a slender syphon tube provided with a stopcock may have the one end inserted in its cover, and the other dipped into a vessel containing a solution of acetate of lead. Whenever the solution has been rendered turbid by the precipitation of sulphuret of lead, it should be renewed. The saturated and fetid milk of lime is evaporated in oblong cast-iron troughs placed in the ash-pit of the furnaces, and the dried lime is partly employed for luting the apparatus, and partly disposed of for a mortar or manure.

By this purifier, and others of similar construction, the gas in the preceding parts of the apparatus, as in the retorts and the condenser, suffers a pressure equal to a column of water about two feet high; and in the last described purifier even a greater pressure. This pressure is not disadvantageous, but is of use in two respects; 1. it shows by a brisk jet of gas when the apparatus is not air-tight, and it prevents common air from entering into the retorts; 2. this compression of the gas favors the condensation of the tar and ammoniacal liquor. The effect of such a degree of pressure in expanding the metal of the ignited retorts is quite inconsiderable, and may be neglected. Two contrivances have, however, been proposed for taking off this pressure in the purifier.

In *fig.* 673, *m m* are two similar vessels of a round or rectangular form, furnished at their upper border with a groove filled with water, into which the under edge of the cover fits, so as to make the vessel air-tight. The cover is suspended by a cord or chain, which goes over a pulley, and may be raised or lowered at pleasure. The vessels themselves have perforated bottoms, *r r′*, covered with wetted moss or hay sprinkled over with slaked and sifted quicklime. The gas passes through the loosely compacted matter of the first vessel, by entering between its two bottoms, rises into the upper space *t*, thence it proceeds to the second vessel, and, lastly, through the pipe *u*, into the gasometer. This method, however, requires twice as much lime as the former, without increasing the purity of the gas.

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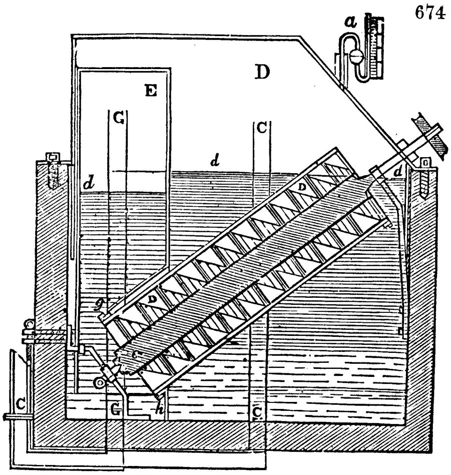

The second method consists in compressing the gas by the action of an Archimedes screw, to such a degree, before it is admitted into the purifier, as that it may overcome the pressure of the column of water in that vessel. *Fig.* 674 exhibits this apparatus in section. D D is the Archimedes worm, the axis of which revolves at bottom upon the gudgeon *e*; it possesses a three-fold spiral, and is turned in the opposite direction to that in which it scoops the water. The cistern which contains it has an air-tight cover. The gas to be purified passes through the pipe C into the space D, over the water level *d*; the upper cells of the worm scoop in the gas at this point, and carry it downwards, where it enters at g into the cavity E of a second cistern. In order that the gas, after it escapes from the bottom of the worm, may not partially return through g into the cavity D, an annular plate $g\ h$ is attached to its under edge, so as to turn over it. The compressed gas is conducted from the cavity E through the pipe G into the purifying machine; a is a manometer, to indicate the elastic tension of the gas in D. On the top of the worm a mechanism is fitted for keeping it in constant rotation.

A perfect purification of light-gas from sulphureted hydrogen, either by milk of lime or a solution of the green sulphate of iron, is attended with some difficulty, when carried so far as to cause no precipitation of sulphuret in acetate of lead, because such a degree of washing is required as is apt to diminish its illuminating power, by abstracting the vapor of the rich oily hydrocarburet which it contains. Moreover, the coal gas obtained towards the end of the distillation contains some sulphuret of carbon, which affords sulphurous acid on being burned, and can be removed by no easy method hitherto known. The lime in the purifier disengages from the carbonate and hydro-sulphuret of ammonia carried over with the gas, especially when it has been imperfectly cooled in the condenser, a portion of ammoniacal gas, which, however, is not injurious to its illuminating power. The best agent for purifying gas would be the pyrolignite of lead, were it not rather expensive, because it would save the trouble of stirring, and require a smaller and simpler apparatus.

The Gasometer.—The gasometer serves not merely as a magazine for receiving the gas when it is purified, and keeping it in store for use, but also for communicating to the gas in the act of burning such a uniform pressure as may secure a steady unflickering flame. It consists of two essential parts; 1. of an under cistern, open at top and filled with water; and 2. of the upper floating cylinder or chest, which is a similar cistern inverted, and of somewhat smaller dimensions, called the gas-holder; see F, *fig.* 669. The best form of this vessel is the round or cylindrical; both because under equal capacity it requires least surface of metal, and it is least liable to be warped by its own weight or accidents. Since a cylindrical body has the greatest capacity with a given surface when its height is equal to its semi-diameter, its dimensions ought to be such that when elevated to the highest point in the water, the height may be equal to the radius of the base. For example, let the capacity of the gas-holder in cubic feet be k, the semi-diameter of its base be x, the height out of the water be h; h is $= x = \sqrt[3]{\frac{k}{3{\cdot}14}}$. This height may be increased by one or two feet, according to its magnitude, to prevent the chance of any gas escaping beneath its under edge, when it is raised to its highest elevation in the water.

The size of the gasometer should be proportional to the quantity of gas to be consumed in a certain time. If 120,000 cubic feet be required, for instance, in 10 hours for street illumination, and if the gas retorts be charged four times in 24 hours, 30,000 feet of gas will be generated in 6 hours. Hence the gasometer should have a capacity of at least 70,000 cubic feet, supposing the remaining 50,000 cubic feet to be produced during the period of consumption. If the gasometer has a smaller capacity, it must be supplied from a greater number of retorts during the lighting period, which is not advantageous, as the first heating of the supernumerary retorts is wasteful of fuel. Some engineers consider that a capacity of 30,000 cubic feet is the largest which can with propriety be given to a gasometer; in which case they make its diameter 42 feet, and its height 23. When the dimensions are greater, the sheet iron must be thicker and more expensive; and the hollow cylinder must be fortified by strong internal cross braces.

The water cistern is usually constructed in this country with cast-iron plates bolted together, and made tight with rust-cement.

In cases where the weight of water required to fill such a cistern might be inconvenient to sustain, it may be made in the form represented in *fig.* 675; which, however, will cost nearly twice as much. Parallel with the side of the cistern, a second cylinder c, of the same shape, but somewhat smaller, is fixed in an inverted position to the bottom of the first, so as to leave an annular space B B between them, which is filled with water, and in which the floating gasometer A plays up and down. The water must stand above the cover of the inverted cylinder. a and b are the pipes for leading the gas in and out. Through an opening in the masonry upon which the gasometer apparatus rests, the space c may be entered, in order to make any requisite repairs.

The water cistern may also be sunk in the ground, and the sides made tight with hydraulic mortar, as is shown in *fig.* 675, and to make it answer with less water, a concentric cylindrical mass of masonry may be built at a distance of 2 or 3 inches within it.

Every large gasometer must be strengthened interiorly with cross iron rods, to stiffen both its top and bottom. The top is supported by rods stretching obliquely down to

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the sides, and to the under edge an iron ring is attached, consisting of curved cast iron bars bolted together; with which the oblique rods are connected by perpendicular ones.

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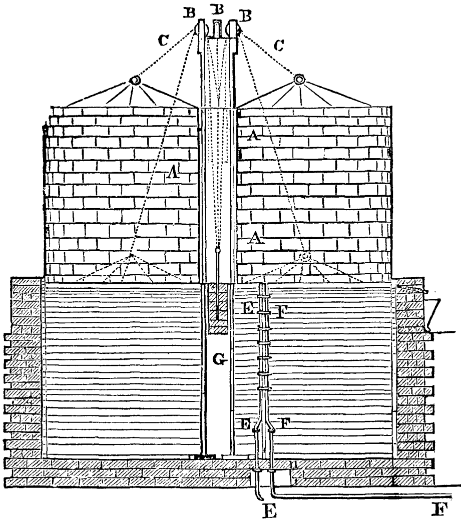

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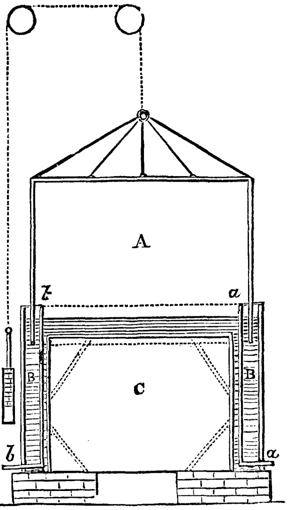

Other vertical rods stretch directly from the top to the bottom edge. Upon the periphery of the top, at the end of the rods, several rings are made fast, to which the gas-holder is suspended, by means of a common chain which runs over a pulley at the centre. Upon the other end of the chain there is a counterpoise, which takes off the greater part of the weight of the gas-holder, leaving only so much as is requisite for the expulsion of the gas. The inner and outer surfaces of the gas-holder should be a few times rubbed over with hot tar, at a few days' interval between each application. The pulley must be made fast to a strong frame.

If the water cistern be formed with masonry, the suspension of the gas-holder may be made in the following way. A A, *fig.* 676, is a hollow cylinder of cast iron, standing up through the middle of the gasometer, and which is provided at either end with another small hollow cylinder G, open at both ends and passing through the top, with its axis placed in the axis of the gas-holder. In the hollow cylinder G, the counterweight moves up and down, with its chain passing over the three pulleys B, B, B, as shown in *fig.* 676. E F are the gas pipes made fast to a vertical iron rod. Should the gasometer be made to work without a counterweight, as we shall presently see, the central cylinder A A, serves as a vertical guide.

In proportion as the gas-holder sinks in the water of the cistern, it loses so much of its weight, as is equal to the weight of the water displaced by the sides of the sinking vessel; so that the gas-holder when entirely immersed, exercises the least pressure upon the gas, and when entirely out of the water, it exercises the greatest pressure. In order to counteract this inequality of pressure, which would occasion an unequal velocity in the efflux of the gas, and of course an unequal intensity of light in its flame, the weight of the chain upon which the gas-holder hangs is so adjusted as to be equal, throughout the length of its motion, to one half of the weight which the gas holder loses by immersion. In this case, the weight which it loses by sinking into the water, is replaced by the portion of the chain which, passing the pulley, and hanging over, balances so much of the chain upon the side of the counterweight; and the weight which it gains by rising out of the water, is counterpoised by the links of the chain which, passing over the pulley, add to the amount of the counterweight. The pressure which the gas-holder exercises upon the gas, or that with which it forces it through the first main pipe, is usually so regulated as to sustain a column of from one to two inches of water; so that the water will stand in the cistern from one to two inches higher within, than without the gas-holder. The following computation will place these particulars in a clear light.

Let the semi-diameter of the gas-holder, equal to the vertical extent of its motion into and out of the water, $= x$; let the weight of a foot square of the side of the gas-holder, including that of the strengthening bars and ring, which remain plunged under the water, be $= p$; then

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1. the weight of the gas-holder in its highest position $= 3\,p\,\pi\,x^2$;
2. the weight of the sides of the gas-holder which play in the water $= 2\,p\,\pi\,x^2$;
3. the cubic contents of the immersed portion of the gas-holder $= \frac{2\,p\,\pi\,x^2}{400}$;
4. its loss of weight in water $= \frac{112}{400}\,p\,\pi\,x^2$;
5. the weight of the gas-holder in its lowest position $=$

$$p\,\pi\,x^2\left(3 - \frac{112}{400}\right) = 2{\cdot}72\,p\,\pi\,x^2;$$

6. the weight of n inches, height of water $= \frac{56}{12}\,n\,\pi\,x^2$;
7. the amount of the counterweight $= \pi\,x^2)\ 3\,p - \frac{56\,n}{12}\Big)$;
8. the weight of the chain for the length $x = \frac{112}{800}\,p\,\pi\,x$.

If we reduce the weight of the gas-holder in its highest and lowest positions to th height of a stratum of water equal to the surface of its top, this height is that of the column of water which would press the gas within the gasometer, were no counterweight employed; it consists as follows:—

9. for the highest position $= \frac{3\,p}{56}$;
10. for the lowest $= \frac{2{\cdot}72\,p}{50}$;

For the case, when the height of the gas-holder is different from its semi-diameter, let this height $= m\,x$; then the height of the water level is—

11. for the highest position $= p\left(\frac{1+2\,m}{56}\right)$;
12. for the lowest $= p\left(\frac{1+1{\cdot}72m}{6}\right)$;
13. the counterweight $= \pi\,x^2\left(p\,(1+2m) - \frac{56n}{12}\right)$;
14. the weight of the equalizing chain $= \frac{112}{800}\,p\,\pi\,m\,x^2$.

For example, let the diameter of the gas-holder be 30 feet, the height 15 (the contents in cubic feet will be 10,597), $p = 4$ pounds; then the counterweight for a height of an inch and a half of water pressure = 3532 pounds; the weight of the chain for a length of 15 feet = 395 pounds. Were no counterweight employed, so that the gas-holder pressed with its whole weight upon the gas, then the height of the equivalent column of water in its highest position = 2·56 inches; and in its lowest, 2·33. The counterweight may hence be lessened at pleasure, if the height of the pressing water-column n be increased. The weight of the equalizing or compensating portion of the chain remains the same. When $n = 2$ inches, for instance, the counterweight = 1886 pounds.

The velocity with which the gas passes along the mains for supplying the various jets of light, may be further regulated by opening the main-cock or slide-valve in a greater or less degree. Gasometers whose height is greater than their semi-diameter, are not only more costly in the construction, but require heavier counterweights and equilibration chains.

The above estimate is made on the supposition of the gas in the gas-holder being of the same specific gravity as the atmospherical air, which would be nearly true with regard to oil gas under the ordinary pressure. But coal gas, whose specific gravity may be taken on an average at about 0·5, exercises a buoyancy upon the top of the gas-holder, which of course diminishes its absolute weight. Supposing the cubic foot of gas to be = 0·0364 pounds, the buoyancy will be $= 0{\cdot}0364\,\pi\,x^3$ pounds; a quantity which deserves to be taken into account for large gasometers. Hence,

15. the weight of the gas-holder in its highest position $= 3\,p\,\pi\,x^2 - 0{\cdot}1143\,x^3$;
16. the counterweight $= \pi\,x^2\left(3\,p - \frac{56\,n}{12}\right) - 0{\cdot}1143\,x^2$;
17. the weight of the chain for the length $x = \frac{112}{800}\,p\,\pi\,x^2\,\frac{0{\cdot}1143\,x^3}{2}$;
18. The height of the water pressure for the highest position, without the counterweight $= \frac{3\,p\,\pi - 0{\cdot}1143\,x}{56\,\pi}$;
19. the same for the lowest position $= 2{\cdot}72\,p$ in feet

The preceding values of p and x are,
(16) = 3147; (17) = 203; (18) = 2·44 inches; (19) = 2·33 inches.

The water columns in the highest and lowest situations of the gas-holder here differ about 0·1 of an inch, and this difference becomes still less when p has a smaller value, for example, 3 pounds, or when the diameter of the gas-holder is still greater.

It would thus appear that for coal-gas gasometers, in which the height of the gas-holder does not exceed its semi-diameter, and especially when it has a considerable size, neither a compensation chain nor a counterweight is necessary. The only thing requisite, is to preserve the vertical motion of the gas-holder by a sufficient number of guide rods or pillars, placed either within the water cistern, or round about it. Should the pressure of the gas in the pipe proceeding from the gasometer, be less than in the gasometer itself, this may be regulated by the main valve, or by water valves of various kinds. Or a small intermediate regulating gasometer may be introduced between the great gas-holder, and the main pipe of distribution. With a diameter of 61 feet in the gas-holder, the pressure in the highest and lowest positions is the same.

The gasometers employed in storing up gas until required for use, occupy, upon the old plan, much space, and are attended with considerable expense in erecting. The water tank, whether sunk in the ground or raised, must be of equal dimensions with the gasometer, both in breadth and depth. The improved construction which we are about to describe, affords a means of reducing the depth of the tank, dispensing with the bridge of suspension, and of increasing at pleasure the capacity of the gasometer, upon a given base; thus rendering a small apparatus capable, if required, of holding a large quantity of gas, the first cost of which will be considerably less than even a small gasometer constructed upon the ordinary plan.

Mr. Tait, of Mile-End Road, the inventor, has, we believe, been for some years connected with gas establishments, and is therefore fully aware of the practical defects or advantages of the different constructions of gasometers now in use. *Fig.* 677 is a section of Mr. Tait's improved contrivance; *a a* is the tank, occupied with water, *b b* two iron columns, with pulley-wheels on the top, *c c*, chains attached to a ring of iron, *d d*, extending round the gasometer, which chains pass over the pulley-wheels, and are loaded at their extremities, for the purpose of balancing the weight of the materials of which the gasometer is composed.

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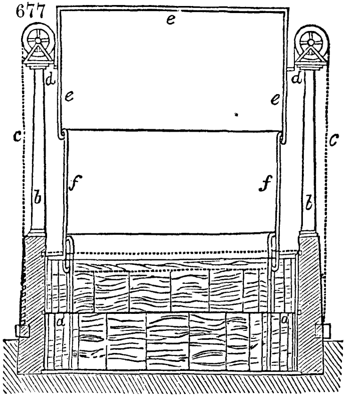


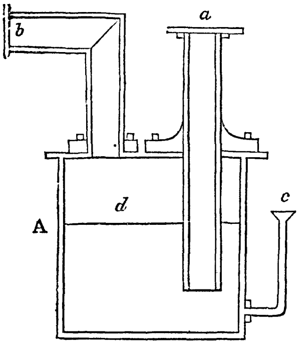
The gasometer is formed by 2 or 3 cylinders, sliding one within the other, like the tubes of a telescope; *e, e, e*, is the first or outer cylinder, closed at the top, and having the ring of iron *d*, passing round it, by which the whole is suspended; *f f*, is the second cylinder, sliding freely within the first, and there may be a third and fourth within these if necessary.

When there is no gas in the apparatus, all the cylinders are slidden down, and remain one within the other immersed in the tank of water; but when the gas rises through the water pressing against the top of the gasometer, its buoyancy causes the cylinder *e* to ascend. Round the lower edge of this cylinder a groove is formed by the turning in of the plate of iron, and as it rises, the edge takes hold of the top rim of the cylinder *f*, which is overlapped for that purpose. The groove at the bottom of the cylinder fills itself with water as it ascends, and by the rim of the second cylinder falling into it, an air-tight hydraulic joint is produced.

Thus, several cylinders may be adapted to act in a small tank of water, by sliding one within the other, with lapped edges forming hydraulic joints, and by supporting the apparatus in the way shown, the centre of gravity will always be below the points of suspension. A gasometer may be made upon this plan of any diameter, as there will be no need of frame-work, or a bridge to support it; and the increasing weight of the apparatus, as the cylinders are raised one after the other, may be counterpoised by loading the ends of the chains *c c*.

The water in the gasometer need not be renewed; but merely so much of it as evaporates or leaks out, is to be replaced. Indeed, the surface of the water in the cistern gets covered with a stratum of coal oil, a few inches deep, which prevents its evaporation, and allows the gas to be saturated with this volatile substance, so as to increase its illuminating powers.

The gasometer may be separated from the purifier by an intermediate vessel, such as is represented *fig.* 678, with which the two gas pipes are connected. A is the cylindrical vessel of cast iron *a*, the end of the gas pipe which comes from the purifier immersed a few inches deep into the liquid with which the vessel is about two thirds filled; *b* is the gas-pipe which leads into the gasometer; *c* is a perpendicular tube, placed over the bottom of the vessel, and reaching to within one third of the top, through which the liquid is introduced into the vessel, and through which it escapes when it overflows the level *d*. In this tube the liquid stands towards the inner level higher, in proportion to the pressure of the gas in the gasometer. The fluid which is condensed in the gas-pipe *b*, and in its prolongation from the gasometer, runs off into the vessel A; and therefore the latter must be laid so low that the said tube may have the requisite declivity. A straight stopcock may also be attached to the side over the bottom, to draw off any sediment.



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II. Application of Light-Gas.

1. *Distribution of the pipes.*—The pressure by which the motion of the gas is maintained in the pipes, corresponds to a certain height of water in the cistern of the gasometer. From the magnitude of this pressure, and the quantity of gas which in a given time, as an hour, must be transmitted through a certain length of pipes, depends the width or the diameter that they should have, in order that the motion may not be retarded by the friction which the gas, like all other fluids, experiences in tubes, and thereby the gas might be prevented from issuing with the velocity required for the jets of flame. The velocity of the gas in the main pipe increases in the ratio of the square root of the pressing column of water upon the gasometer, and therefore by increasing this pressure, the gas may be forced more rapidly along the remoter and smaller ramifications of the pipes. Thus it happens, however, that the gas will be discharged from the orifices near the gasometer, with superfluous velocity. It is therefore advisable to lay the pipes in such a manner, that in every point of their length the velocity of discharge may be nearly equal. This may be nearly effected as follows:—

From experiment it appears that the magnitude of the friction, or the resistance which the air suffers in moving along the pipes, under a like primary pressure, that is, for equal initial velocity, varies with the square root of the length. The volume of gas discharged from the end of a pipe is directly proportional to the square of its diameter, and inversely as the square root of its length; or, calling the length L, the diameter D, the cubic feet of gas discharged in an hour k; then $k = \frac{D^2}{\sqrt{L}}$. Experience likewise shows, tha for a pipe 250 feet long, which transmits in an hour 200 cubic feet of gas, one inch is a sufficient diameter.

Consequently, $200 : k :: \frac{1}{144\sqrt{250}} : \frac{D^2}{\sqrt{L}}$; and $D = \frac{\sqrt{k}\,\sqrt{L}}{455{,}000}$.

From this formula the following table of proportions is calculated.

Number of bic feet per hour.	Length of pipe, in feet.	Diameter, in inches.
50	100	0·40
250	200	1·00
500	600	1·97
700	1000	2·65
1000	1000	3·16
1500	1000	3·87
2000	1000	4·47
2000	2000	5·32
2000	4000	6·33
2000	6000	7·00
6000	1000	7·75
6000	2000	9·21
8000	1000	8·95
8000	2000	16·65

These dimensions are applicable to the case where the body of gas is transmitted through pipes without being let off in its way by burners, that is, to the mains which conduct the gas to the places where it is to be used. If the main sends off branches for burners, then for the same length the diameter may be reduced, or for like diameter the length may be greater. For example, if a pipe of 5·32 inches, which transmits 2000 cubic feet through a length of 2000 feet, gives off, in this space, 1000 cubic feet of gas; then the remainder of the pipe, having the same diameter, can continue to transmit the gas through a length of 2450 feet $= \left(\frac{450,000}{k}\right)^2$ with undiminished pressure for the purposes of lighting. Inversely, the diameter should be progressively reduced in proportion to the number of jets sent off in the length of the pipe.

Suppose, for instance, the gasometer to discharge 2000 cubic feet per hour, and the last point of the jets to be at a distance of 4000 feet. Suppose also that from the gasometer to the first point of lighting, the gas proceeds through 1000 feet of close pipe, the diameter of the pipe will be here 4·47 inches; in the second 1000 feet of length, suppose the pipe to give off, at equal distances, 1000 cubic feet of gas, the diameter in this length (calculated at 1500 cubic feet for 1000 feet long) = 3·87 inches; in the third extent of 1000 feet, 600 cubic feet of gas will be given off, and the diameter (reckoning 700 cubic feet for 1000 feet long) will be 2·65 inches; in the fourth and last space (for 200 cubic feet in 1000 feet long) the pipe has a diameter of only an inch and a half, for which, in practice, a two-inch cast iron pipe is substituted; this being the smallest used in mains, into which branch pipes can be conveniently inserted.

The same relations hold with regard to branch pipes through which the gas is transmitted into buildings and other places to be illuminated. If such pipes make frequent angular turnings, whereby they retard the motion of the gas, they must be a third or a half larger in diameter. The smallest tubes of distribution are never less than one fourth of an inch in the bore.

Where, from one central gas work, a very great quantity of light is required in particular localities, there ought to be placed near these spots gasometers of distribution, which, being filled during the slack hours of the day, are ready to supply the burners at night, without making any considerable demand upon the original main pipe. Suppose the first main be required to supply 8000 cubic feet in the hour, for an illumination of 8 hours, at the distance of 2000 feet, a pipe 10⅔ inches in diameter would be necessary; but if two or three gasometers of distribution, or station gasometers, be had recourse to, into which the gas during the course of 24 hours would flow through the same distance continuously from the central gas works, the quantity required per hour from them would be only one third of 8,000 = 2666·6 cubic feet; consequently the diameter for such a pipe is only 6·15 inches.

All the principal as well as branch pipes, whose interior diameter exceeds an inch and a half, are made of cast iron from 6 to 8 feet long, with elbow pipes cast in them where it is necessary. These pipe lengths are shown in *fig.* 679, having at one end a wide socket *a*, and at the other a nozzle *b*, which fits the former. After inserting the one in the other in their proper horizontal position, a coil of hemp soaked with tar is driven home at the junction; then a luting of clay is applied at the mouth, within which a ring of lead is cast into the socket, which is driven tight home with a mallet and blunt chisel.

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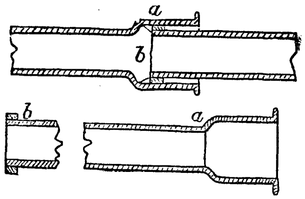

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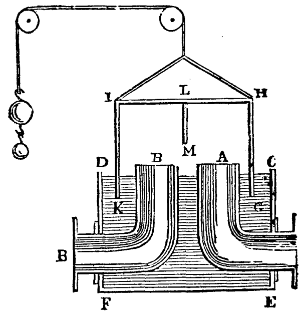

The pipes should be proved by a force pump before being received into the gas works; two or three lengths of them should be joined before laying them down, and they should be placed at least two feet below the surface, to prevent their being affected by changes of temperature, which would loosen the joints. The tubes for internal distribution, when of small size, are made of lead, copper, wrought iron, or tin.

Instead of a stopcock for letting off the gas in regulated quantities from the gasometer, a peculiarly formed water or mercurial valve is usually employed. *Fig.* 680 shows the mode of construction for a water trap or lute, and is, in fact, merely a gasometer in miniature. C D E F is a square cast iron vessel, in the one side of which a pipe A is placed in communication with the gasometer, and in the other, one with the main B. The moveable cover or lid H G I K has a partition, L M, in its middle. If this cover be raised by its counterweight, the gas can pass without impediment from A to B; but if the counterweight be diminished so as to let the partition plate L M sink into the water, the communication of the two pipes is thereby interrupted. In this case the water-level stands in the compartment A so much lower than outside of it, and in the compartment B, as is equivalent to the pressure in the gasometer; therefore the pipes A and B must project thus far above the water. In order to keep the water always at the same height, and to prevent it from flowing into the mouths of these pipes, the rim C D of the outer vessel stands somewhat lower than the orifices A B; and thence the vessel may be kept always full of water.

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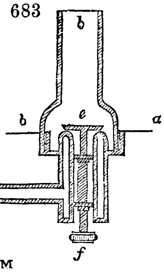

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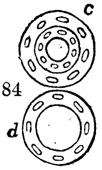

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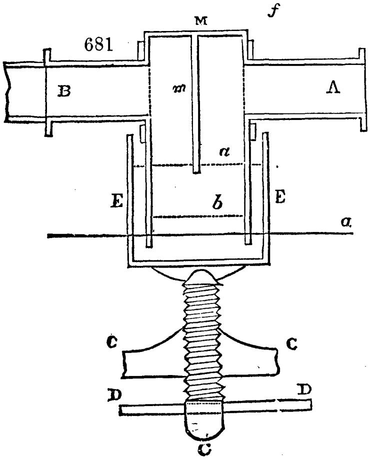

If a quicksilver valve be preferred, it may be constructed as shown in *fig.* 681. A B are the terminations of the two gas pipes, which are made fast in the rectangular iron vessel M. E is an iron vessel of the same form, which is filled with quicksilver up to the level *a*, and which, by means of the screw G, which presses against its bottom, and works in the fixed female screw C C, may be moved up or down, so that the vessel M may be immersed more or less into the quicksilver. The vessel M is furnished with a vertical partition *m*; the passage of the gas from A to B is therefore obstructed when this partition dips into the quicksilver, and from the gradual depression of the vessel E by its screw, the interval between the quicksilver and the lower edge of the partition, through which the gas must enter, may be enlarged at pleasure, whereby the pressure of the gas in B may be regulated to any degree. The transverse section of that interval is equal to the area of the pipe or rather greater; the breadth of the vessel M from A to B amounts to the double of that space, and its length to the mere diameter of A or B. The greatest height to which the partition *m* can rise out of the quicksilver, is also equal to the above diameter, and in this case the line *a* comes to the place of *b*. The vertical movement of the outer vessel E, is secured by a rectangular rim or hoop which surrounds it, and is made fast to the upper part of the vessel M, within which guide it moves up and down. Instead of the lever D D, an index with a graduated plate may be employed to turn the screw, and to indicate exactly the magnitude in the opening of the valve.

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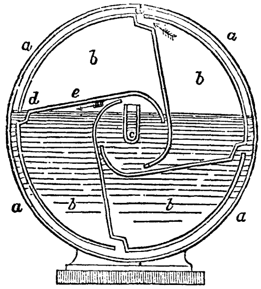


In order to measure the quantity of gas which passes through a pipe for lighting a factory, theatre, &c., the gas-meter is employed, of whose construction a sufficiently precise idea may be formed from the consideration of *fig.* 682, which shows the instrument in a section perpendicular to its axis.

Within the cylindrical case *a*, there is a shorter cylinder *b b*, shut at both ends, and moveable round an axis, which is divided into four compartments, that communicate by the opening *d*, with the interval between this cylinder and the outer case The mode in which this cylinder turns round its axis is as follows:—The end of the tube *c*, which is made fast to the side of the case, and by which the gas enters, carries a pivot or gudgeon, upon which the centre of its prop turns; the other end of the axis runs in the cover, which here forms the side of a superior open vessel, in which, upon the same axis, there is a toothed wheel. The vessel is so far filled with water, that the tube *c* just rises above it, which position is secured by the level of the side vessel. When the gas enters through the tube *c*, by its pressure upon the partition *e* (*fig.* 682), it turns the cylinder from right to left upon its axis, till the exterior opening *d* rises above the water, and the gas expands itself in the exterior space, whence it passes off through a tube at top. At every revolution, a certain volume of gas thus goes through the cylinder, proportional to its known capacity. The wheel on the axis works in other toothed wheels, whence, by means of an index upon a graduated disc or dial, placed at the top or in front of the gas-meter, the number of cubic feet of gas, which pass through this apparatus in a given time, is registered.

B. *Employment of the gas for lighting.*—The illuminating power of different gases burned in the same circumstances, is proportional, generally speaking, to their specific gravity, as this is to the quantity of carbon they hold in combination. The following table exhibits the different qualities of gases in respect to illumination.

Density or specific gravity		Proportion of light afforded by coal gas to oil gas.
Coal gas.	Oil gas.	
0·659	0·818	100 : 140
0·578	0·910	100 : 225
0·605	1·110	100 : 250
0·407	0·940	100 : 354
0·429	0·965	100 : 356
0·508	1·175	100 : 310
Mean 0.529	0·96	100 : 272

In the last three proportions, the coal gas was produced from coals of middle quality in the first three proportions, from coals of good quality; and therefore the middle proportion of 100 to 270 may be taken to represent the fair average upon the great scale On comparing the gas from bad coals, with good oil gas, the proportion may become 100 to 300. Nay, coal gas of specific gravity 0·4, compared to oil gas of 1·1, gives the proportion of 1 to 4. A mould tallow candle, of 6 in the pound, burning for an hour, is equivalent to half a cubic foot of ordinary coal gas, and to four tenths of a foot of good gas. The flame of the best argand lamp of Carcel, in which a steady supply of oil is maintained by pump-work, consuming 42 grammes = 649 grains English in an hour, and equal in light to 9·38 such candles, is equivalent to 3·75 cubic feet of coal gas per hour. The sinumbra lamp, which consumes 50 grammes = 772 grains English, of oil per hour, and gives the light of 8 of the above candles, is equivalent to the light emitted by 3·2 cubic feet of coal gas burning for an hour. A common argand lamp, equal to 4 candles, which consumes 30 grammes = 463 grains English per hour, is represented by 1·6 cubic feet of gas burning during the same time. A common lamp, with a flat wick and glass chimney, whose light is equal to 1·13 tallow candles, and which consumes 11 grammes = 169·8 grains English per hour, is represented by 0·452 of a cubic foot of gas burning for the same time.

Construction of the Burners.—The mode of burning the gas as it issues from the jets has a great influence upon the quantity and quality of its light. When carbureted hydrogen gas is transmitted through ignited porcelain tubes, it is partially decomposed with a precipitation of some of its carbon, while the resulting gas burns with a feebler flame. Coal gas, when kindled at a small orifice in a tube, undergoes a like decomposition and precipitation. Its hydrogen, with a little of its carbon, burns whenever it comes into contact with the atmospherical air, with a bluish colored flame; but the carbonaceous part not being so accendible, takes fire only when mixed with more air; therefore at a greater distance from the beak, and with a white light from the vivid ignition of its solid particles. Upon this principle pure hydrogen gas may be made to burn with a white instead of its usual blue flame, by dusting into it particles of lamp black, or by kindling it at the extremity of a tube containing finely pulverized zinc. The metallic particles become ignited, and impart their bright light to the pale blue flame. Even platinum wire and asbestos, when placed in the flame of hydrogen gas, serve to whiten it. Hence it has been concluded, that the intensity of light which a gas is capable of affording is proportional to the quantity of solid particles which it contains, and can precipitate in the act of burning. Carbonic oxyde gas burns with the feeblest light next to hydrogen, because it deposites no carbon in the act of burning Phosphureted hydrogen gives a brilliant light, because the phosphoric acid, into which its base is converted during the combustion, is a solid substance, capable of being ignited in the flame. Olefiant gas, as also the vapor of hydro-carbon oil, emits a more vivid light than common coal gas; for the first is composed of two measures of hydrogen and two measures of the vapor of carbon condensed into one volume; while the last contains only one measure of the vapor of carbon in the same bulk, and combined with the same proportion of hydrogen. Olefiant gas may therefore be expected to evolve a double quantity of carbon in its flame, which should emit a double light.

The illuminating power of the flame of coal gas is, on the contrary, impaired, when, by admixture with other species of gas which precipitate no carbon, its own ignited particles are diffused over a greater surface. This happens when it is mixed with hydrogen, carbonic oxyde, carbonic acid, and nitrogen gases, and the diminution of the light is proportional to the dilution of the coal gas.

In like manner the illuminating power of coal gas is impaired, when it is consumed too rapidly to allow time for the separation and ignition of its carbonaceous matter; it burns, in this case, without decomposition, and with a feeble blue flame. 1. This occurs when the light-gas is previously mixed with atmospherical air, because the combustion is thereby accelerated throughout the interior of the flame, so as to prevent the due separation of carbon. A large admixture of atmospherical air makes the flame entirely blue. 2. When it issues, with considerable velocity, from a minute orifice, whereby the gas, by expansion, gets intimately mixed with a large proportion of atmospherical air. If the jet be vertical, the bottom part of the flame is blue, and the more so the less carbon is contained in the gas. The same thing may be observed in the flame of tallow, wax, or oil lights. The burning wick acts the part of a retort, in decomposing the fatty matter. From the lower part of the wick the gases and vapors of the fat issue with the greatest velocity, and are most freely mixed with the air; while the gases disengaged from the upper part of the wick compose the interior of the flame, and being momentarily protected from the action of the atmosphere, acquire the proper high temperature for the deposition of carbon, which is then diffused on the outer surface in an ignited state, and causes its characteristic white light. Hence with coal gas, the light increases in a certain ratio with the size of the flame as it issues from a larger orifice, because the intermixture of air becomes proportionately less. 3. If by any means too great a draught be given to the flame, its light becomes feebler by the rapidity and completeness with which the gas is burned, as when too tall a chimney is placed over an argand burner, see *fig.* 683. *Fig.* 684, *c*, is a view of the upper plate, upon which the glass chimney *b* rests. The gas issues through the smaller openings of the inner ring, and forms a hollow cylindrical flame, upon the outside as well as the inside of which the atmospherical air acts. The illuminating power of this flame may be diminished at pleasure, according as more or less air is allowed to enter through the orifices beneath. With a very full draught the light almost vanishes, leaving only a dull blue flame of great heating power, like that of the blowpipe, corresponding to the perfect combustion of the gas without precipitation of its carbon. 4. On the other hand, too small a draught of air is equally prejudicial; not merely because a portion of the carbon thus escapes unconsumed in smoke, but also because the highest illuminating power of the flame is obtained only when the precipitated charcoal is heated to whiteness; a circumstance which requires a considerable draught of air. Hence the flame of dense oil gas, or of oil in a wick, burns with a yellow light without a chimney; but when it is increased in intensity by a chimney draught, it burns with a brilliant white flame.

From the consideration of the preceding facts, it is possible to give to coal gas its highest illuminating power. The burners are either simple beaks perforated with a small round hole, or circles with a series of holes to form an argand flame, as shown in *fig.* 684, or two holes drilled obliquely, to make the flame cross, like a swallow's tail, or with a slit constituting the sheet of flame called a bat's wing, like most of the lamps in the streets of London. These burners are mounted with a stopcock for regulating the quantity of gas.

The height of the flame, which with like pressure depends upon the size of the orifice, and with like orifice upon the amount of pressure, the latter being modified by the stopcock, is, for simple jets in the open air, as follows:—

Length of the flame	2	3	4	5	6 inches.
Intensity of the light -	55·6	100	150	197·8	247.4
Volume of gas consumed -	60·5	101·4	126·3	143·7	182·2
Light with equal consumption	100	109	131	150	150

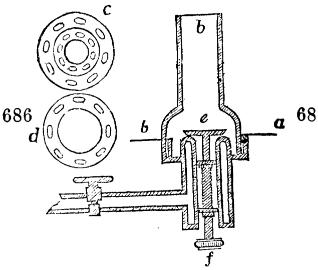
When the length exceeds five inches, nothing is gained in respect to light. For oil gas the same statements will serve, only on account of its superior richness in carbon, it does not bear so long a flame without smoke. Thus:

Length of the flame	1	2	3	4	5 inches.
Intensity of the light	22	63·7	96·5	141	178
Gas consumed	33·1	78·5	90	118	153
Light with equal consumption	100	122	159	181	174

The diameter of the orifice for single jets, or for several jets from the same beak, is one twenty-eighth of an inch for coal gas, and one forty-fifth for oil gas.

When several jets issue from the same burner, the light is improved by making all the flames unite into one. In this case the heat becomes greater, for the combined flame presents a smaller surface to be cooled, than the sum of the smaller flames. The advantage gained in this way may be in the ratio of 3 to 2, or 50 per cent. In an argand burner the distances of the orifices for coal gas should be from $\frac{16}{100}$ to $\frac{18}{100}$ of an inch, and for oil gas $\frac{12}{100}$. If the argand ring has 10 orifices, the diameter of the central opening should be $= \frac{4}{10}$ of an inch; if 25 orifices, it should be one inch for coal gas; but for oil gas with 10 orifices, the central opening should have a diameter of half an inch, and for 20 orifices, one inch. The pin holes should be of equal size, otherwise the larger ones will cause smoke, as in an argand flame with an uneven wick. The glass chimney is not necessary to promote the combustion of an argand coal gas flame, but only to prevent it from flickering with the wind, and therefore it should be made so wide as to exercise little or no influence upon the draught. A narrow chimney is necessary merely to prevent smoke, when a very strong light with a profusion of gas is desired. Oil gas burned in an argand beak requires a draught chimney, like a common argand lamp, on account of the large quantity of carbon to be consumed. The most suitable mode of regulating the degree of draught can be determined only by experiment, and the best construction hitherto ascertained is that represented in *fig.* 685. *Fig.* 686 exhibits the view from above, of the rim or ring *c*, upon which the chimney *b* stands, and which surrounds the perforated beak. The ring is made of open fretwork, to permit the free passage of air upwards to strike the outside of the flame. The thin annular dsic *d*, which is laid over its fellow disc *c*, in the bottom of the chimney-holder, being turned a little one way or other, will allow more or less air to pass through for promoting, more or less, the draught or ventilation. The draught in the central tube of the burner may be regulated by the small disc *e*, whose diameter is somewhat smaller than that of the ring of the burner, and which, by turning the milled head *f*, of the screw, may be adjusted with the greatest nicety, so as to admit a greater or smaller body of air into the centre of the cylindrical flame.

686 685



In mounting gas-lights, and in estimating beforehand their illuminating effects, we must keep in mind the optical proposition, that the quantity of light is inversely as the square of the distance from the luminous body, and we must distribute the burners accordingly. When, for example, a gas-light placed at a distance of ten feet, is required for reading or writing to afford the same light as a candle placed at a distance of two feet; squaring each distance, we have 100·4; therefore $\frac{100}{4} = 25$, shows us that 25 such lights will be necessary at the distance of 10 feet.

Concerning portable gas-light, with the means of condensing it, and carrying it from the gas works to the places where it is to be consumed, we need say nothing, as by the improvements lately made in the purification and distribution of coal gas, the former system has been superseded.

It is well known that light gas deteriorates very considerably by keeping, especially when exposed to water over an extensive surface; but even to a certain degree over oil, or in close vessels. An oil gas which when newly prepared has the specific gravity of 1·054, will give the light of a candle for an hour, by consuming 200 cubic inches; will, after two days, give the same light by consuming 215 cubic inches per hour; and after four days, by consuming 240 cubic inches in the like time. With coal gas the deterioration appears to be more rapid. When newly prepared, if it affords the light of a candle with a consumption of 400 cubic inches per hour, it will not give the same light after being kept two days, except with a consumption of 430 inches; and after four days, of 460. Oil gas three weeks old has become so much impaired in quality that 600 inches of it were required per hour to furnish the light of a candle. All light gas should be used therefore as soon as possible after it is properly purified.

Economical considerations.—The cost of gas-light depends upon so many local circumstances, that no estimate of it can be made of general application; only a few leading points may be stated. The coals required for heating the retorts used to constitute one half of the quantity required for charging the retorts themselves. When five retorts are heated by one fire, the expenditure for fuel is only one third of that when each retort has a fire. The coke which remains in the retorts constitutes about 60 per cent. of the weight of the original coal; but the volume is increased by the coking in the proportion of 100 to 75. When the coke is used for heating the retorts, about one half of the whole is required. If we estimate the coke by its comparative heating power, it represents 65 per cent. of the coals consumed. One hundred pounds of good coal yield in distillation 10 pounds of ammoniacal liquor, from which sulphate or muriate of ammonia may be made, by saturation with sulphuric or muriatic acid, and evaporation. The liquor contains likewise some cyanide of ammonia, which may be converted into Prussian blue by the addition of sulphate of iron, after saturation with muriatic acid.

Two hundred pounds of coal afford about 17 pounds of tar. This contains in 100 pounds 26 pounds of coal oil, and 48 pounds of pitch. The tar is sometimes employed as a paint to preserve wood and walls from the influence of moisture, but its disagreeable smell limits its use. The coal oil, when rectified by distillation, is extensively employed for dissolving caoutchouc in making the varnish of waterproof cloth, and also for burning in a peculiar kind of lamps under the name of naptha. Oil of turpentine, however, is often sold and used for this purpose, by the same name. If the coal oil be mixed with its volume of water, and the mixture be made to boil in a kettle, the mingled vapors when passed through a perforated nozzle may be kindled, and employed as a powerful means of artificial heat. The water is not decomposed, but it serves by its vapor to expand the bulk of the volatile oil, and to make it thereby come into contact with a larger volume of atmospherical air, so as to burn without smoke, under a boiler or any other vessel. The pitch may be decomposed into a light-gas.

The relative cost of light from coal gas and oil gas may be estimated as one to six at least. Rosin gas is cheaper than oil gas. See Rosin.

I shall conclude this article with a summary of the comparative expense of different modes of illumination, and some statistical tables.

One pound of tallow will last 40 hours in six mould candles burned in succession, and costs 8*d.*; a gallon of oil, capable of affording the light of 15 candles, for 40 hours, costs 5*s.*; being therefore ½ of the price of mould candles, and $\frac{6}{15}$ of the price of dips. The cost of wax is about 3½ times that of tallow; and coal gas, as sold at the rate of 9*s.* for 1000 cubic feet, will be one sixth the price of mould candles; for 500 cubic inches of coal gas give a light equal to the above candle for an hour; therefore 40 × 500 = 20,000 cubic inches = 11·57 cubic feet, worth 1¼*d.*, which multiplied by 6 gives 7½*d.*, the average price of mould candles per pound.

The author of the article *Gas-light* in the Encyclopædia Britannica, observes, in reference to the economy of this mode of illumination, that while the price of coal, in consequence of the abundant and regular supply of that article, is liable to little fluctuation, the cost of wax, tallow, and oil, on account of the more precarious nature of the sources from which they are obtained, varies exceedingly in different seasons. "Assuming that a pound of tallow candles, which last when burned in succession forty hours, costs ninepence" (seven-pence halfpenny is the average price), "that a gallon of oil, yielding the light of 600 candles for an hour, costs two shillings" (five shillings is the lowest price of a gallon of such oil as a gentleman would choose to burn in his lamp), "that the expense of the light from wax is three times as great as from tallow, and that a thousand cubic feet of coal gas cost nine shillings;" he concludes the relative cost to be for the same quantity of light,—from wax, 100; tallow, 25; oil, 5; and coal-gas, 3. I conceive the estimate given above to be much nearer the truth; when referred to wax called 100, it becomes, for tallow, 28·6; oil, 14·3; coal-gas, 4·76.

Gas-lighting has received a marvellous development in London. In the year 1834, the number of gas lamps in this city was 168,000, which consumed daily about 4,200,000 cubic feet of gas. For the purpose of generating this gas, more than 200,000 chaldrons, or 10,800,000 cubic feet of coals were required.

For the following valuable statistical details upon gas-light, my readers are indebted to Joseph Hedley, Esq., engineer, of the Alliance Gas Works, Dublin; a gentleman who to a sound knowledge of chemistry, joins such mechanical talent and indefatigable diligence, as qualify him to conduct with success any great undertaking committed to his care. He has long endeavored to induce the directors of the London gas-works to employ a better coal, and generate a more richly carbureted gas, which in much smaller quantity would give as brilliant a light, without heating the apartments unpleasantly, as their highly hydrogenated gas now does. Were his judicious views adopted, coal gas would soon supersede oil, and even wax candles, for illuminating private mansions.

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Copy of a paper laid before a Committee of the House of Commons, showing not only the relative values of the Gases produced at the undermentioned places, but showing in like manner the relative economy of Gas, as produced at the different places, over candles. By Joseph Hedley, Esq.

Names of the Places where experiments were made.	Illuminating power of a single Jet of Gas-flame four inch high, taken by a comparison of Shadows.	The Jet of Gas burnt, four inches high, consumed per hour and was equal to the Candles in the last column.	Gas required to be equal to 100 lbs. of mould Candles, 6 to the lb., 9 inches long each.*	Selling price of Gas per meter per 1000 cubic feet.	Cost of Gas equal in illuminating power to 100 lbs. of Candles.†	Average discount allowed off the charge for Gas.	Net cost of Gas equal to 100 lbs. of Candles.	Specific gravity of the Gas.
	Equal to Candles	*Cubic Feet.*	*Cubic Feet.*	*s. d.*	*L. s. d.*	*Per Cent.*	*L. s. d.*	
Birmingham; Birmingham and Staffordshire; two Companies	2·572	1·22	2704	10 0	1 7 0	9	1 4 7	·541
Stockport - -	3·254	·85	1489	10 0	0 14 11	12½	0 13 0	·539
Manchester -	3·060	·825	1536	8 0	0 12 3	11¼	0 10 10	·534
Liverpool Old Company‡	2·369	1·1	2646	10 0	1 6 5	6¼	1 4 9	·462
Liverpool New Gas Company	4·408	·9	1164	10 0	0 11 8	6¼	0 9 10	·580
Bradford - -	2·190	1·2	3123	9 0	1 8 1	12½	1 4 6	·420
Leeds - -	2·970	·855	1644	8 0	0 13 2	6¼	0 12 4	·530
Sheffield - -	2·434	1·04	2440	8 0	0 19 6	6¼	0 18 3	·466
Leicester - -	2·435	1·1	2575	7 6	0 19 3	15	0 16 5	·528
Nottingham -	1·645	1·3	4200	9 0	1 17 9	15	1 11 3	·424
Derby - -	1·937	1·2	3521	10 0	1 15 4	15	1 10 0	·448
Preston - -	2·136	1·15	3069	10 0	1 10 8	15	1 6 2	·419
London - -	2·083	1·13	3092	10 0	1 10 11	none allowed.	1 10 11	·412

* 100 lbs. of candles are estimated to burn 5700 hours. † The candles cost 3*l.* 2*s.* 6*d.*

‡ The Liverpool Old Company have since resorted to the use of Cannel coal, and consequently very nearly assimilate to the Liverpool New Company in illuminating power.

MEMORANDUM.—It will not fail to be observed that in deducing the comparative value between candles and gas by these experiments, the single jet (and in every instance, of course, it was the same) has been the medium. This, however, though decidedly the most correct way of making the comparative estimate of the illuminating power of the several gases, is highly disadvantageous in the economical comparison, inasmuch as gas burnt in a properly regulated argand burner, with its proper sized glass, air aperture, and sufficient number of holes, gives an advantage in favor of gas consumed in an argand, over a jet burner, of from 30 to 40 per cent. At the same time it must not be overlooked, that in many situations where great light is not required, it will be found far more economical to adopt the use of single jets, which, by means of swing brackets and light elegant shades, become splendid substitutes for candles, in banking establishments, offices, libraries, &c. &c.

NOTE.—In Glasgow, Edinburgh, Dundee, Perth, and the Scotch towns generally, the Parrot or Scotch Cannel coal is used; in illuminating power and specific gravity the gas produced is equal to that from the best description of Cannel coal in England. The price per 1000 cubic feet ranges about 9s., with from 5 to 30 per cent. off for discounts, leaving the net price about 9s. to be equal in the above table to 100 lbs. of candles.

Epitome of Experiments made in Gas produced from different qualities of Coal, and consumed in different kinds of Burners:

Tried at the Sheffield Gas Light Company's Works, and laid before a Committee of the House of Commons. By Joseph Hedley, Esq.

Date 1835.	Description of Burner.	Species of Coal.	Specific gravity of Gas.	Distance of Candle from Shadow.	Gas consumed per Hour.	Height of Gas Flame.	Equal to Mould Tallow Candles, 6 to the pound, 9 inches long each.	Gas equal to 100 lbs. of Mould Candles.	Cost of Gas at 8*s.* per 1000 cubic feet.	Cost of 100 lbs. of Mould Candles at 7*s.* 6*d* per dozen lbs
May				*Inches*	*Cubic Feet.*	*Inches*	*Candles.*	*Cubic Feet.*	*L. s. d.*	*L. s. d.*
8	Single Jet	Deep Pit	·410	75	1·	4	2·36	2415	0 19 3½	3 2 6
9	Ditto	Mortormley	·450	74	·95	4	2·434	2224	0 17 9½	
9	Ditto	Cannel	·660	61¼	·7	4	3·54	1127	0 9 0	
8	Argand 14 holes	Deep Pit	·410	34	3·3	3½	11·53	1631	0 13 0½	
9	Ditto	Mortormley	·450	33	3·1	3½	12·24	1443	0 11 6½	
9	Ditto	Cannel	·660	29	2·6	3½	15·85	935	0 7 5¾	

Copy of Experiments made at the Alliance Gas Company's Works in Dublin, during the past year 1837. By Joseph Hedley, Esq.

Results of experiments on the qualities of various coals for the production of gas; its value in illuminating power; produce of coke, and quality; and other particulars important in gas-making:—

1*st Experiment*, *Saturday*, *May* 27, 1837.—Deane coal (Cumberland), 2 cwts. of 112 lbs. each (or 224 lbs.) produced 970 cubic feet of gas; 4 bushels of coke of middling quality; specific gravity of the gas, 475. Consumed in a single-jet burner, flame 4 inches high, $1\frac{4}{10}$ths cubic feet per hour; distance from shadow 76 inches, or 2·3 mould candles. Average quantity of gas made from the charge (6 hours) 4·33 cubic feet per lb., or 9,700 cubic feet per ton of 20 cwts. Increase of coke over coal in measure, not quite·30 per cent. Loss in weight between coal, coke, and breize 56 lbs., converted into gas, tar, ammonia, &c.

2*d Experiment*, *May* 28.—Carlisle coal (Blenkinsopp). 224 lbs. produced 1010 cubic feet of gas, 4 bushels of coke of good quality though small; increase of coke over coal in measure not quite 30 per cent. Loss in weight, same as foregoing experiment. Average quantity of gas made from the charge (6 hours) 4·5 cubic feet per lb. or 10,080 per ton.

Illuminating power of the Gas.

	Consumed per hour, single jet.	Distance from candle.	Equal to candles.	Specific gravity.
	feet.	*inches.*		
At the end of the first hour -	$1\frac{1}{10}$	70	2·72	·475
Ditto ditto with 20-hole argand burner - -	5	25	21·33	·475
When charge nearly off - -	$1\frac{4}{10}$	85	1·84	·442
When charge quite off, with 20-hole argand burner - -	9	100	not 1	·266

3*d Experiment*, *May* 29.—Carlisle coal (Blenkinsopp). 112 lbs. produced 556 cubic feet of gas. Other products, loss of weight, &c., same proportion as foregoing experiment. Average quantity of gas made from the charge (6 hours) 4·96 cubic feet per lb., or 11,120 per ton.

In this experiment the quantity of gas generated every hour was ascertained; the illuminating power, the specific gravity, and the quantity of gas consumed by the single jet with a flame 4 inches high, was tried at the end of each hour, with the respective gases generated at each hour; and the following is a table of results.

RESULTS.

Hour.	Gas produced.	Consumed per hour, per single jet, 4 inches high.	Specific gravity.	Distance of candle from shadow.	Illuminating power equal to mould candles.
	cubic feet.	*cubic feet.*		*inches.*	
1st.	150	11½-10ths or 1·15	·534	70	2·72
2d.	120	11	·495	75	2·36
3d.	95	12	·344	75	2·36
4th.	95	15	·311	80	2·08
5th.	80	17	·270	85	1·81
6th.	16	29	·200	100	not one
Total	556 or	92⅓ or 2	feet 9 inches.		

Average of the above gas, 6-hour charge.

92⅓ 16-10ths, nearly ·359 81 2·03

Average of the above gas at 4-hour charge.

115 12⅓-10ths, ·421 75 2·36

Production of gas in 6 hours 556 feet, or at the rate of 11,120 cubic feet per ton.
Ditto in 4 hours 460 feet, or at the rate of 9,200 ditto

The relative value of these productions of gas is as follows, viz.:

11,120 at 16-10ths per hour nearly (or 1·5916 accurately), and equal to 203 candles; the 11,120 feet would be equal to and last as long as 1597 candles, or 266$\frac{1}{6}$ lbs. of candles.

9200 at 12$\frac{1}{8}$-10ths per hour (or 1·2375 accurately), and equal to 236 candles; the 9200 feet would be equal to 1949 candles, or 324$\frac{5}{6}$ lbs. candles.

Now 266$\frac{1}{6}$ lbs. of mould candles, at 7*s.* 6*d.* per dozen lbs., will cost 8*l.* 6*s.* 4½*d.*, whilst
324$\frac{5}{6}$ lbs. of do. do. at 7*s.* 6*d.* per do. do. 10*l.* 3*s.*

Showing the value of 4-hour charges over 6-hour charges; and of 9,200 cubic feet over 11,120 cubic feet.

Note —9500 cubic feet of Wigan cannel coal gas are equal in illuminating power to 859 1-6th lbs of candles, which at 7*s.* 6*d.* per dozen lbs. will cost 25*l.* 10*s.* 5½*d.* It is also found that any burner with superior gas will consume only about half the quantity it would do with common gas.

4th Experiment, May 30th.—Cannel and Cardiff coal mixed ½ and ½, together 112 lbs., produced 460 feet of gas; 2 bushels of coke of good quality; increase of coke over coal in measure, about 30 per cent.; loss in weight, 41 lbs.; coke weighed 71 lbs., no breize. Average quantity of gas made from the charge (4 hours), 4·1 cubic feet per lb., or 9·200 per ton.

Illuminating power.—At the end of the first hour.

	Candles.		Cubic feet.
Distance of candle from shadow - - -	73 or 2·49	Consumed per hour, single jet, 4 inches high -	12-10ths.
At end of 2d hour, do.	70 or 2·72	Do. do. do.	11½-10ths.
At end of 3d hour.	This gas very indifferent.		
Average of the three -	70 or 2·72	Do. do. do.	11½-10ths.

Specific gravity 3·44; 5 feet per hour, with a 20-hole argand burner, equal to 14·66 candles.

5th Experiment, May 31st.—Carlisle coal, 112 lbs. produced 410 feet of gas; other products, same as in former experiments with this coal, but heat very low.

Illuminating power and produce of gas.

410 ft.	1st hour	120 cubic feet
	2d	100
	3d	90
	4th	100

Average of this gas: specific gravity, 540; distance of candle from shadow, 55 inches, or 4·4 candles consumed per single jet, 9-10ths of a cubic foot per hour. 20-hole argand burner, 4 feet per hour, equal to 21·33 candles.

It is possible, from the superior quality of this gas, that a little of the cannel gas made for a particular purpose, may have got intermixed with it in the experimental gasholder and apparatus.

A variety of other experiments were tried on different qualities of coal, and mixtures of ditto, too tedious to insert here, though extremely valuable, and all tending to show the superior value of gas produced at short over long charges; and also showing the importance and value of coal producing gas of the highest illuminating power; among which the cannel coal procured in Lancashire, Yorkshire, and some other counties of England and Wales, and the Parrot or splent coal of Scotland, stand pre-eminent.

Note.—In all the foregoing experiments the same single-jet burner was used; its flame in all instances exactly 4 inches high.

The coal when drawn from the retort was slaked with water, and after allowing some short time for drying, was weighed.

A TABLE of the number of hours Gas is burnt in each month, quarter, and year.

Time of Burning.	July.	August.	Sept.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Mid. quar.	Mic. quar.	Xms. quar.	Lady day quar.	Total of year.	
o'clock.																		
From dusk to 6	—	—	2	31	62	80	65	33	4	—	—	—	—	2	173	102	277	For Sundays off, deduct one seventh.
— 7	—	14	22	62	92	111	96	61	31	4	—	—	4	36	265	188	493	
— 8	—	40	52	93	122	142	127	89	62	28	4	—	32	92	357	278	759	
— 9	13	71	82	124	152	173	158	117	93	58	29	8	95	166	449	368	1078	
— 10	44	102	112	155	182	204	189	145	124	88	60	38	186	258	541	458	1443	
— 11	75	133	142	186	212	235	220	173	155	118	97	68	277	350	633	548	1808	
— 12	106	164	172	217	242	266	251	201	186	148	122	98	368	442	725	638	2173	
All night -	217	307	345	421	473	527	512	411	382	295	243	195	732	869	1421	1305	4327	
Morning from 4	—	16	48	80	110	137	137	98	71	28	2	—	30	64	327	306	727	
— 5	—	—	18	49	80	106	106	70	40	3	—	—	3	18	235	216	472	
— 6	—	—	—	18	50	75	75	42	9	—	—	—	—	—	143	126	269	
— 7	—	—	—	—	20	44	44	14	—	—	—	—	—	—	64	58	122	

Copy of a Paper submitted to a Committee of the House of Commons in the Session of 1837,
of England; and procured by actual Survey and

Name of the Place where Gas Works are situated.	Price of Gas per Meter, and Discounts allowed.	Price of Coal, and Description; delivered per Ton.	Average Quantity of Gas made per Ton of Coals.	Coke made from a Ton of Coal.	Selling Price of Coke.	Material usual to heat Retorts.	Quantity used per Ton of Coal.	No. of Public or Street Lamps supplied.	Description —— Size or Sort.	Price paid per Annum for Ditto	Who lights, cleans, puts out, and repairs.
			Cu. ft							L. s. d.	
Birmingham Gas Company.	10s. per meter cub. feet. Discounts 10l. to 30l. 2½ 30l. to 50l. 5 50l. to 75l. 7½ 75l. to 100l. 10 100l. & upwards 15 per an. per cent.	Lump coal from West Bromwich pits, risen much of late. 1837, 11s. 10d.	6,500	32 bushels.	2s. 1d per quarter delivered, or about 3d. per bushel.	Slack.	About 5 cwt. of slack, at 6s. per ton, 25 per cent.	490	Batswings. 460 30	1 10 0 2 0 0	Company, and provides posts, services, &c.
Birmingham and Staffordshire.	10s. per meter cub. feet. Discounts as above.	From West Bromwich pits, 1837, 9s. 3d.	6,500	24 bush. but larger measure than Birmingham.	2s. 10d. per sack of 8 bushels.	Slack. and Tar.	5 cwt. of slack, at 4s. 25 per cent.	1,500	Batswings.	average 1 18 0	Ditto.
Macclesfield.	10s. per meter cub. feet. Discounts Above and not exceeding per cent. 50l. 75l. 5 75l. 100l. 7½ 100l. 125l. 10 125l. 150l. 12½ 150l. 175l. 15 175l. 200l. 17½ 200l. & upwards 20	Common, 8s. average 1834.	6,720	12 cwt.	10s. per ton.	Coke.	No account kept.	220	Ditto.	2 10 0	Company.
Stockport.	10s. per meter cub. feet. Disco'nts same as Macclesfield. Macclesfield discounts taken from Stockport card.	Coal 10s. 6d. cannel 19s. 6d. about half and half used. Average 15s. 1834.	7,800	7 cwt.	6s. 8d. per ton.	Coal, coke, and tar.	Ditto.	230	Ditto	[illegible] 0 1834. 2 0 0 1837.	Comrs. provide lamps & posts. Company's service light, repair, clean, and extinguish.
Manchester.	10s. per m. cub. ft. 1834. 9s. and 8s. — 1837. Discounts and under per cent. 50l. 100l. 2½ 100l. 150l. 5 150l. 200l. 7½ 200l. 225l. 10 225l. 250l. 12½ 250l. 300l. 15 300l. 400l. 17½ 400l. & upwards 20	15s. 2d. average. Oldham, Watergate, Wigan } cannel Mixed, 1834.	9,500	14 cwt.	Ditto.	Coke.	4, 2-3ds cwt.	2,375	Single jets and flat flames, about half and half.	1 2 0 2 0 0	Commissioners of police.
Liverp'l Old Company, 1834.	10s. per meter cub. feet. Discounts 10l. & under 50l. 2½ 30l. to 100l. 5 100l. to 200l. 7½ 300l. and upwards 10 per ct.	7s. 3d. per ton of 112 lbs. per cwt. Ormskirk or Wigan slack.	8,200	11¾ cwt.	8s. 4d. per ton of 112 lb. per cwt.	Slack, 7s. 3d. per ton.	6½ cwt.	1,700 30	Batswings. 1 jet, 2 — 3 — 4 —	4 10 0 2 5 0 2 13 0 3 2 9 3 13 1	Company light, clean, put out, and repair
Ditto, ditto, Liverpool New Gas and Coke, 1833.	In 1835, this Company 10s. per meter cub. feet. Discounts same as Liverpool Old Comp'ny.	resorted to the 18s. all cannel Wigan.	use of 9,500	cannel co 13 cwt.	al similar 7s. 6d. per ton.	to the L Coke and slack.	iverpool 5½ cwt.	New G Only a few.	as and Coal Argands.	Compa 4 0 0	ny, producing Commissioners.
Bradford, 1834.	9s. per meter cubic feet to large consumers. Discounts 20l. to 30 5 30l. to 40 7½ 40l. to 60 10 60l. to 80 12½ 80l. to 100 15 100l. & upwards 20 per cent. Small Consumers, 10s. per meter cub. feet. and 5 per cent. off from 10l. to 20l.	8s. 6d. per ton. 3 sorts used average. Slack 5s. 6d. Low moor 8s. 10d. Catherine slack 8s.	8,000	13 cwt.	12s. per ton.	Coke.	8½ cwt.	220	Batswings	2 12 6	Company light, repair, &c.
Leeds, 1834.	8s. per meter cubic feet. Discounts 2½ per cent. 15l. 5 on half- 30l. 7½ yearly 50l. 10 payments. 100l.	8s. per ton average. 2-3ds. common 7s. 1-3d cannel 10s.	6,500	12 cwt.	7s. 6d. per ton.	Ditto	5½ cwt.	517	Ditto.	2 12 6	Commissioners, except extinguishing, for which Comp'ny pay 3s. 10d per lamp.
Sheffield, 1835.	8s. per meter cubic feet. Disc'nts same as Leeds.	7s. 9d. per ton average. 3 sorts used, 1, 2-10ths can'el, at 16s. 8, 2-10ths deep pit, 7s. 1-10th silkstone, 10s.	8,000	10 cwt. of saleable coke.	10s. per ton.	Ditto	3½ cwt.	600	Ditto	2 10 0	Company provide lamps, clean, repair, put out, &c.
Leicester, 1837.	7s. 6d. per meter cub. ft. Disc'nts on half-yearly rental, not exceeding 10l., 5 per cent. Above and not exceeding per cent. 10l. 20l. 7½ 20l. 30l. 10 30l 40l. 12½ 40l. 50l. 15 50l. 60l. 20 60l. & upwards 25	13s. 6d. average. Derbyshire soft coal.	7,500	4 quarters	10s. 8d. or 2s. 8d. per qr.	Coke, tar, &c.	About 1-3d of coke.	4 4	Ditto	2 18 6	Company light, put out, and clean
Derby, 1834.	10s. per meter cub. feet. Discounts 5 to 35 per cent.	Same coal used as at Leicester.	7,000	Ditto.	Ditto.	Coke.	Ditto.	219	Ditto.	2 2 0 2 7 0	Commissioners light, put out, &c.
Nottingham, 1834.	9s. per meter cubic feet. Discounts as above.	Ditto.	7,000	Ditto.	Ditto.	Ditto	Ditto.	200	Ditto.	3 3 0	Commissioners light, clean, repair, &c.
London, 1834.	16s. per meter cub. feet. No discounts.	17s. average. Newcastle.	8,500	36 bush.	12s. per chaldron.	Ditto.	3 bush.	26,280	Ditto	4 0 0	Company light, clean, put out, but not repair
Ditto, 1837.	Ditto	Ditto.	8,500	Ditto.	Ditto.	Ditto.	Ditto.	20,400	Ditto.	4 0 0	[illegible]

being a Synopsis of the proceedings of the undermentioned principal Gas-Light Establishments Experiments between the Years 1834 and 1837. By Joseph Hedley, Esq.

No. of Hours, or Time burnt in the Year.	Gas consumed in each Lamp per Hour.	Rate per Meter Cubic Feet received for Ditto.	Amount deducted for cleaning, lighting, extinguishing, providing Lamp Posts, &c.	Per Centage of Loss of Gas made.	Greatest Quantity of Gas delivered in One Night.	Duration of Charges.	Method of Purification.	Number of Gas Holders.	Specific Gravity of the Gas.	Distance of Candle from Shadow.	Gas equal to Candles. Gas burnt in a single Jet Four Inches high.	Gas consumed per Hour with a Four Inch Flame.	Gas flame reduced to Candle burnt per Hour.	Height of Gas Flame equal to Light from Candle.
		s. d.	*s. d.*		*Cubic Feet.*					*Inch.*	*C'ndles*	*Cu. ft.*	*Cu. ft.*	*Inch.*
226 nights, or 2938 hours, 9 months, omitting 5 nights for moons.	5 feet per hour.	30 10 40 18	18 0	Receives net about 6*s.* 8*d.* per meter cubic feet.	48 millions in the year.	6 hours.	Dry lime.	4, and 2 in the town, and large new gas station.	·453	72	1,929	1·22	·8	2½
234 nights, or 3042 hours.	Ditto.	1 3½	18 0	Receives net about 5*s.* 6*d.* per meter cubic feet.	85 millions in the year.	Ditto.	Ditto.	6, and 6 in the town 7 miles off.	·455	72	1,929	1·22	·8	2½
8 months, omitting 5 nights for moons.	4 feet per hour.	3 0	12 0	Could not say.	80,000. Total for year about 15 millions.	8 hours.	Ditto.	3 gas holders.	Not taken	70	204	Not taken	8	2[illegible]
8 months, 4 nights omitted for moons. 237 nights—2800 hours.	Ditto.	2 6	12 6	Ditto.	65,000. Total for year about 12 millions.	Ditto.	Ditto.	4 gas holders.	·539	64	2,441	·85	·55	2 5-8
3390 hours.	1 foot. 2 feet, per hour.	6 6 5 6	nothing	About 15 to 17½ per cent receive about 7*s.* 4*d.* per meter cubic feet, public and private. Nearly all by meter.	500,000. Total for year 100 millions.	6 hours.	Wet lime.	10 gas holders, and 2 in the town.	534	66	2,295	·825	475	[illegible]
3600 hours.	5 feet per hour.	4 4	12 0	Could not learn in the absence of the manager.	360,000. Total for year 72 millions.	8 hours, large retorts, holding 6 cwt. each.	Wet and dry lime, principally dry.	8 gas holders in all, 4 in the town, 1000 yards off the works.	862	75	1,777	1·1	·75	2 5-8
nearly similar	results,	which	see.											
3000 hours.	3½ feet per hour.	5 6	nothing	Nearly all by meter.	Not sufficiently long at work.	4 hours.	Wet lime.	2 large gas holders.	·580	55	3,306	·9	[illegible]	[illegible]
8 months, omitting 7 nights. 2600 hours to 4 o'clock in the morning.	5 feet per hour.	3 1	12 6	Receive 8*s.* per meter cubic feet, less 5½ per cent.	42,500. Total for year 8,619,000.	8 hours.	Dry lime.	4 gas holders.	·420	78	1,643	·12	·9	3
2330 hours.	4 feet per hour.	5 2	3 10	Receive for public and private 6*s.* 8*d.* per meter cubic feet. Public 5*s.* private 7*s*; meters used 5 to 1 for private rental.	176,000. Total for year 31 millions.	6 hours	Ditto.	5 gas holders.	·530	67	2,228	·855	[illegible]	[illegible]
2200 hours.	Ditto.	3 2½	18 0	Receive for public and private lts. 5*s.* per meter cubic feet. Public 3*s.* 2½*d.*, private 5*s.* 9½*d.* Few meters used.	220,000. Total for year 40 millions.	Ditto.	Ditto.	4 gas holders, and 2 more erecting.	·466	74	1,826	1·04	·736	2[illegible]
From August 14th to September 1st, omitting 3 nights for moons, 3000 hours.	5 feet per hour.	3 4½	7 0	Not sufficiently long, at 7*s.* 6*d.*	Total for year 18 millions.	Ditto.	Ditto.	3 gas holders, and 1 erecting.	·528	74	1,826	1·1	75	2[illegible]
3173 hours, from August to May.	Ditto.	4 0 nearly	—	Lose about 17½ per cent.	Ditto.	Ditto.	Wet lime.	4 gas holders.	·448	83	1,453	1·2	·925	3
All the year, 4337 hours	Ditto.	3 0 nearly	—	Could not learn.	Ditto.	Ditto.	Ditto.	—	·424	90	1,234	1·3	1 175	3
4227 hours, all the year.	4 feet per hour	4 0	12 0	Receive for public and private lights 7*s.* public, 4*s.* private, 8*s.* few meters used.	Total for year 1000 millions. Longest night 4,910,000.	Ditto.	Ditto	130 gas holders.	·412	80	1,562	1·12	84	2[illegible]
Ditto.	Ditto.	4 0	12 0	Ditto.	Total for year 1460 millions. Longest night 7,190,000.	Ditto	Ditto.	176 gas holders.	·412	80	1,562	1·12	·84	2[illegible]

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A TABLE showing the rate per Thousand Cubic feet received for any Burner consuming from ½ a Cubic foot to 10 Cubic feet per hour, at any given price per annum, and to the times below stated. By Joseph Hedley, Esq.

Time of Burning per annum.	No. of hours*	Single Jets.			2 Jets.			3 Jets.			Small Argand.			Large Argand.			Fancy and extravagant Burners.		
		Cu. ft. ½	Cu. ft. ¾	Cu. ft. 1	Cu. ft. 1¼	Cu. ft. 1½	Cu. ft. 1¾	Cu. ft. 2	Cu. ft. 2½	Cu. ft. 3	Cu. ft. 3½	Cu. ft. 4	Cu. ft. 4½	Cu. ft. 5	Cu. ft. 6	Cu. ft. 7	Cu. ft. 8	Cu. ft. 9	Cu. ft. 10
From Dusk to 8 o'clock - - - - - -	781	2·56	1·706	1·28	1·026	·853	·731	·64	·5132	·4268	·3658	·3201	·2846	·2561	·2134	·1829	·16	·1423	·128
ditto and Sundays - - -	902	2·216	1·478	1·108	·887	·739	·633	·554	·4434	·3695	·3168	·2771	·2464	·2217	·1848	·1584	·1383	·1232	·1108
ditto and from 6 o'clock mornings	1050	1·904	1·27	·952	·762	·635	·544	·476	·381	·3174	·272	·2381	·2116	·1905	·1587	·136	·119	·1058	·0952
ditto and Sundays and from ditto	1172	1·706	1·138	·853	·682	·569	·487	·426	·3412	·2844	·2438	·2133	·1896	·1706	·1422	·1219	·1067	·0948	·0853
9 o'clock - - - - -	1054	1·896	1·264	·948	·759	·632	·542	·474	·3794	·3162	·271	·2371	·2108	·1897	·1581	·1355	·1165	·1054	·0948
ditto and Sundays - -	1221	1·638	1·092	·819	·675	·546	·463	·409	·3376	·273	·234	·2047	·182	·1638	·1365	·117	·1024	·091	·0819
ditto and from 6 o'clock mornings	1323	1·510	1·006	·755	·604	·503	·431	·378	·3022	·2519	·2158	·1889	·1678	·1511	·1259	·1079	·0945	·0839	·0755
ditto and Sundays and from ditto	1490	1·342	·894	·671	·536	·447	·383	·335	·2684	·2236	·1918	·1675	·1492	·1312	·1118	·0959	·0839	·0746	·0671
10 o'clock - - - - - -	1367	1·462	·974	·731	·585	·487	·418	·366	·2926	·2438	·209	·1829	·1626	·1463	1219	·1045	·0914	·0813	·0731
ditto and Sundays - - -	1586	1·26	·84	·63	·504	·42	·36	·315	·2522	·2101	·1802	·1576	·14	·1261	·1051	·0901	·0789	·07	·0630
ditto and from 6 o'clock mornings	1636	1·222	814	·611	·489	·407	·349	·305	·2444	·2037	·1746	·1528	·1358	·1222	·1019	·0873	·0764	·0679	·0611
ditto and Sundays and from ditto	1855	1·078	·718	·539	·431	·359	·308	·269	·2156	·1796	·154	·1347	·1198	·1078	·0898	·077	·0674	·0599	·0539
11 o'clock - - - - - -	1680	1·19	·794	·595	·476	·397	·34	·297	·238	·1984	·17	·1488	·133	·119	·0992	·085	·0744	·0665	·0595
ditto and Sundays - - -	1951	1·024	·682	·512	·409	·341	·293	·256	·2048	·1707	·1466	·1281	·1138	·1024	·0854	·0733	·064	·0569	·0512
ditto and from 6 o'clock mornings	1949	1·026	684	·513	·41	·342	·294	·256	·2052	·171	·1466	·1282	·114	·1026	·0855	·0733	·0641	·057	·0513
ditto and Sundays and from ditto	2220	·9	·6	·45	·36	·3	·257	·225	·1802	·1501	·1286	·1126	·1	·0981	·0751	·0643	·0563	·05	·045
12 o'clock - - - - - -	1993	1·	·668	·502	·4	·334	·287	·251	·2006	·1672	·1434	·1254	·1114	·1003	·0836	·0717	·0627	·0557	·0502
ditto and Sundays - - -	2316	·862	·574	·432	·345	·287	·247	·215	·1726	·1439	·1236	·1079	·0958	·0863	·0719	·0618	·0539	·0479	·0432
ditto and from 6 o'clock mornings	2262	·884	·59	·442	·353	·295	·255	·221	·1768	·1476	·1274	·1105	·0982	·0884	·0737	·0637	·0552	·0491	·0442
ditto and Sundays and from ditto	2585	·772	·514	·387	·309	·257	·221	·193	·1546	·1289	·1104	·0967	·0858	·0773	·0645	·0552	·0483	·0429	·0387
1 o'clock - - - - - -	2306	·866	·578	·434	·347	·289	·247	·217	·1734	·1445	·1238	·1080	·0962	·0867	·0723	·0619	·0542	·0481	·0434
ditto and Sundays - - -	2681	·746	·498	·373	·298	·249	·213	·186	·1492	·1243	·1066	·0932	·0828	·0746	·0621	·0533	·0466	·0414	·0373
ditto and from 6 o'clock mornings	2575	·776	·518	·388	·31	·259	·222	·194	·1552	·1294	·111	·0971	·0862	·0776	·0647	·0555	·0485	·0431	·0388
ditto and Sundays and from ditto	2950	·678	·452	·339	·271	·226	·193	·169	·1356	·113	·0968	·0847	·0754	·0678	·0565	·0484	·0424	·0377	·0339
All night - - - - - -	4327	·462	·308	·231	·185	·154	·132	·115	·6924	·077	·066	·0578	·0515	·0462	·0385	·033	·0289	·0257	·0231

To use the Table.—Select the hour to which it is agreed the gas is to burn,—9, 10, 11 o'clock, Sundays, &c., as the case may be, and the description of the burner.—Multiply the decimal number opposite to it by the amount in shillings agreed to be paid per annum, and the product will be the sum received per m. cubic feet for the gas.

Example.—Suppose a small argand, which should burn 3½ feet per hour, is agreed for till 9 o'clock at 2*l.* per annum. Look along the line of 9 o'clock till you arrive at the column of 3½ feet per hour, and you find the number, 271. Multiply this number by 40*s.* and the result gives 10*s.* 10*d.* per m. cubic feet. But suppose instead of keeping to 9 o'clock the party burns till 1 o'clock, Sundays and mornings, and by enlarging the holes or height of flame consumes 8 cubic feet of gas per hour; then you have the number, ·0424, which multiplied by 40*s.*, still the price paid, gives 1*s.* 8*d.* per m. cubic feet only, and so on for any greater or lesser variation of the agreement.

* The "number of hours" includes ¼ of an hour allowed for shutting shops, and 1 hour's extra burning on Saturday nights

Trials of, and Experiments on, various Kinds of Coal as regards the Production o Gas from each, and its Quality or Illuminating Power; by Joseph Hedley, Esq., Consulting Gas Engineer, London.

Note.—In all the experiments the gas was passed through a governor, on a pressure of 5 10ths of an inch.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Name and Description of Coal.	Through an Aperture or Tube without a Burner, 2 10ths of an Inch, turned full on.—Height of Flame.	Gas Consumed per Hour by ditto.	Single Jet Hole, 28th of an Inch Diameter, turned full on.—Height of Flame.	Gas consumed per Hour by ditto	Single Jet Flame, restricted to 4 Inches High, consumed per Hour.	Equal in Illuminating Power to	Argand with 20 Holes; outer Diameter 9 10ths of an Inch; inner ditto 6·4 of an Inch; Holes 40th of an Inch Diameter; Distances apart, 1 10th of an Inch; full Illuminating Power equal to 12 Candles; consumed per hour.	Arranged with 30 Holes; outer Diameter 1 1-4 Inch; inner ditto 7-8 of an Inch; Holes 40th of an Inch Diameter; Distances apart, 1-10th of an Inch; full Illuminating Power equal to 25 Candles; Consumption per Hour.	Specific Gravity.	Total Production of Gas from 20 lbs of Coal, and Duration of Charge.		At End of 1st Half-hour.	2d Half-hour.	3d ditto.	4th ditto.	5th ditto.	6th ditto.
	Inch's	Cubic Feet.	Inches.	Cubic Feet.	Cubic Feet.	Candles	Cubic Feet.	Cubic Feet.	Parts of 1·000.	Cubic Feet.	Hours.	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic. Feet.	Cubic Feet.
Lismahago, or Glasgow Cannel - - - -	21to22	12	7½	12·1	7·2	2·77	2·3	3·9	·737	101	2½	39	27	22	11	2	
Newcastle coal	18	16	6	16·2	11·1	1·75	5·	7·5	.475	104	3	30	20	18	15	15	6
Welsh Cannel	22	11	9	12·1	7·1	3·	2·	3·	·737	.102	2	50	30	20	2		
Pelaw, Newcastle Coal -	18	16	5½	16·1	11·1	1·75	5·	7·5	·444	102	3	29	20	17	16	14	6
Pelton, ditto -	18	16	5¾	16·2	11·2	1·73	5·	7.5	.437	102	3	28	20	19	16	14	6
Bickerstaff, Liverpool ditto	19	14	6½	16·2	11·1	2·04	4·6	6·5	.475	102	3	30	24	18	16	10	4
Wigan Cannel	22	12	8½	13·1	7.2	3·	2·	3·	.606	100	2½	38	30	18	10	4	
Blenkinsopp, Carlisle Coal	27	16	6½	15·1	11·1	1·87	4·6	7.	·521	100	3	28	24	18	18	10	2
Neath Coal -	18	16	7	19·1	12·1.	1·75	5·22	7·5	·468	100	3	26	21	20	14	12	7

Note.—The candle here used was a composition candle, with plaited wick, requiring no snuffing giving at least one third more light than mould tallow candles.

Attention to the preceding tabular statement of experiments is important, as exhibiting several very important facts, particularly interesting at this moment to the science of gas-lighting, *and now for the first time made public.*

It will not fail to be observed by these experiments that all the coals produced nearly equal *quantities* of gas, notwithstanding the variable characters and qualities of the coal. The greatest quantity produced being at the rate of 11·648 cubic feet per ton of 20 cwt., the smallest 11·200 cubic feet. All these experiments were performed with the greatest care, and under *precisely similar circumstances* as to pressure, manufacture, &c., &c. The *time* in which the *quantity* of gas is produced from the several coals varies considerably, and deserves notice, as it most materially affects the economy of production —*that coal being the most valuable,* all other things being alike, which yields or gives out its gas in the *shortest time;* and particular attention is claimed to this fact. For the more ready reference to the table the columns are numbered. No. 11 exhibits this difference, and it will also be seen by this column that the *time* varies as the *quality* of the coal, the best coal yielding its gas in *two* hours, and the worst in *three* hours.

Another most important, material, and interesting fact is established by these experiments—that the *flow of gas* is *as its density*—demonstrated by the variation in the heights of the flames, as shown in column No. 1, being 18 inches in the inferior gases to 22 inches in the superior; while the quantity of gas required to supply these flames is in the inverse ratio of their heights, the *longer* flame requiring but *twelve* cubic feet to maintain it, when the *shorter* flame, from the inferior gas, required *sixteen* cubic feet. See column No. 2.

Remarkable as this difference in the heights of the flames and the consumption is it is not so great as the difference caused by the quality or illuminating power of the several gases, shown by columns Nos. 5 and 6; where it will be seen that the consumption of the best gas per hour was only $\frac{7}{10}$ of a cubic foot, and its light was equal to 3 candles, while that of the worst gas was $\frac{12}{10}$ of a cubic foot, and its lights equal only to 1·75 candles, or nearly, the best to the worst, as 1 to 3.

The next column, No. 7, exhibits similar results as to the superior value or illuminating power of one gas over another. In this case an *argand burner* was used. The best gas required only *two* feet to be equal to *twelve* candles, while the inferior required *five* feet to be equal to the same.

And in column No. 8, in which another and superior *argand burner* was used, the best gas required only *three* feet to be equal to *twenty-five* mould candles, while the inferior required *seven and a half* feet: from this it results that the 7½ cubic feet of inferior gas, to be equal to the 3 feet of good gas, should have given light equal to *sixty-two and a half* candles, whereas they only gave light equal to *twenty-five* candles, *so great is the difference in the* QUALITIES *of gas for producing light.*

Whilst on the subject of the illuminating power and the value of one gas over another, it will not fail to be observed, by the table, that another great difference also exists, caused by the use of particular burners; as, for example, the best gas in column No. 5., where the single jet was used, required *seven-tenths* of a cubic foot to be equal to *three* candles, whilst the same gas in column No. 7., where a 20-hole argand burner was used, required only *two* feet to be equal to *twelve* candles; and in column No. 8., where a 30-hole argand burner was used, only *three* feet were required to be equal to *twenty-five* candles; demonstrating the fact that a great and extraordinary improvement in the quantity of illuminating power is effected by the simple increase or enlargement of the burner, affording, where great light in one position is required, a most extraordinary economy in the use of gas, shown in fact practically by the recent introduction of the celebrated "Bude" light, patented by Mr. Goldsworthy Gurney.

TABULAR STATEMENT, deduced from the foregoing Experiments, showing the Cost of Candles to produce as much light as 9,000 Cubic Feet of Gas would afford, being the Product of One Ton of Coal. (The candles are moulds, 6 to the pound, 9 inches long, and each candle is calculated to burn 9½ hours. Cost of Candles 7½*d.* per pound, or 7*s.* 6*d.* per dozen pounds.)

Candles would cost, to be equivalent to	Where a single Jet Burner is used.	Where a 20-hole Argand Burner is used.	Where a 30-hole Argand Burner is used.	Where a Bude Burner is used, according to Statement of Company.
	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
Common coal gas - - - - - -	10 18 6	15 15 8	21 18 0	59 2 7
Good do. - - - - - - - -	25 18 4	39 9 6	54 16 7	148 0 9

TABLE, also deduced from the foregoing, showing the Cost of Gas at the several Prices undermentioned, and equivalent to 100 lbs. of Mould Candles, costing 3*l.* 2*s.* 6*d.*

Description of Gas.	If burnt in a Single Jet Gas equal to 100 lbs. of Mould Candles.	Gas would cost at per thousand Cubic Feet.			If burnt in a 20-hole Argand Burner, Gas equal to 100 lbs. of Candles.	Gas would cost at per thousand Cubic Feet.			If burnt in a 30-hole Argand Burner, Gas equal to 100 lbs. of Candles.	Gas would cost at per thousand Cubic Feet.		
	Cubic feet.	5*s.*	7*s.*	9*s.*	Cubic feet.	5*s.*	7*s.*	9*s.*	Cubic Feet.	5*s.*	7*s.*	9*s.*
		s. *d.*	*s.* *d.*	*s.* *d.*		*s.* *d.*	*s.* *d.*	*s.* *d.*		*s.* *d.*	*s.* *d.*	*s.* *d.*
Common	2,687	13 5	18 9	24 2	1,781	8 10	12 5	16 0	1,282	6 5	8 11	11 6
Good -	1,072	5 4	7 5	9 7	712	3 6	4 11	6 4	513	2 7	3 7	4 7

I have received from Mr. Hedley, an engineer of great eminence and experience, plans and drawings of gas works and of apparatus of the most approved and modern construction, and on the very largest scale as to extent of business or manufacture: also plans and drawings of a gas work on a smaller scale, with its corresponding apparatus. In the first, or large work, purification by wet lime, before described, is used; in the latter, by dry lime.

The large work referred to is calculated for and is arranged to contain 400 retorts, 12 wet-lime purifiers, and 2 washers; 12 large double or telescopic gas-holders, capable of storing 1,000,000 cubic feet of gas; and coal stores capable of holding 10,000 tons of coal.

The smaller work is calculated for and will contain 40 retorts, 2 dry-lime purifiers, and a wash vessel; 2 gas-holders capable of storing 50,000 cubic feet of gas; and coal stores sufficient for 1000 tons of coal.

Fig. 687. is the side elevation (front view) of a gas work capable of containing 400 retorts, and all their dependencies.

Fig. 688. is the plan of the retort house, coal stores, tanks, gas-holders, &c., on the largest scale and most approved form, viz., A the retort house, 300 feet long, 56 feet wide; B, retort beds; C, chimney stack; D, flues; E, hydraulic mains; F, coal stores, each 300 feet long, 30 feet wide; G, condensers; H, engine houses; J, wash vessels; K, purifiers and connections; L, lime store and mixing tub; M, smiths' and fitters' shop; N, refuse lime pits; O, meter houses; P, tar tank; Q, tanks, gas-holders, bridges, columns, valves, and connections; R, governors; S, coke stores; T, inlet pipes; V, outlet pipes; W, house and offices; X, stores.

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Fig. 689. **Transverse section and elevation of a bed of 5 D retorts**; A, transverse section; B, elevation.

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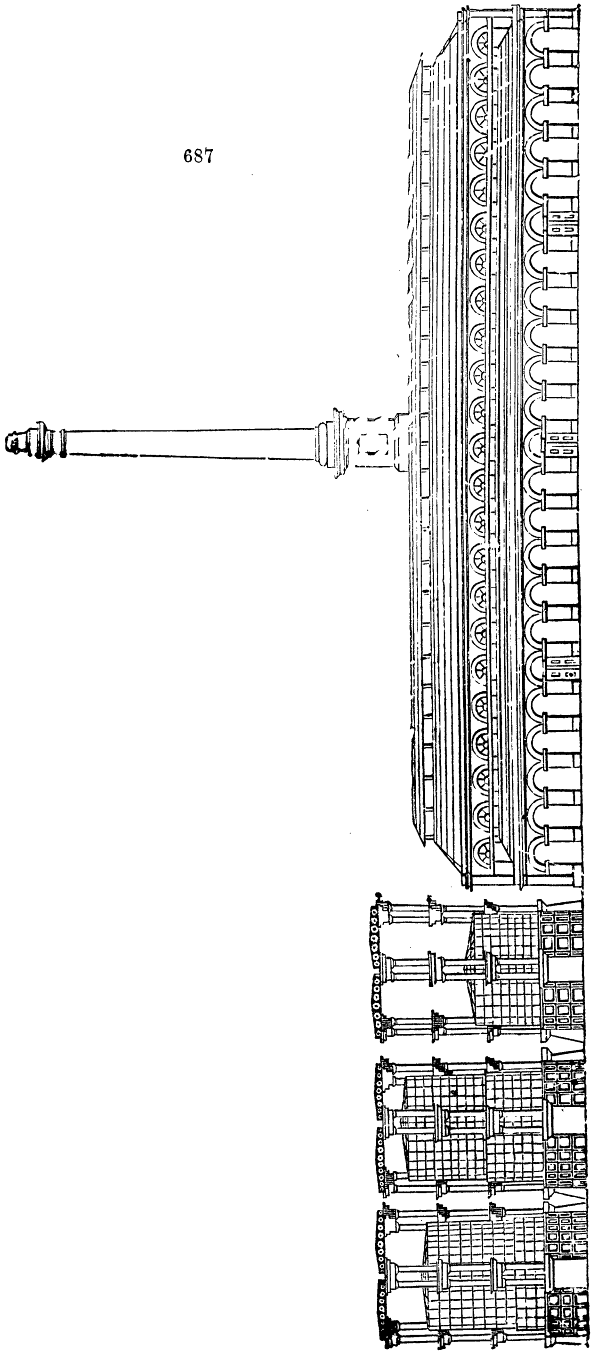

Fig. 690. Longitudinal section of a bed of 5 D retorts.

Fig. 691. Elevation of an upright air condenser, consisting of 5 chambers, with a series of 10-inch pipes.

Fig. 692. Elevation of a double or telescopic gas-holder, of a modern and approved form, with part of tank.

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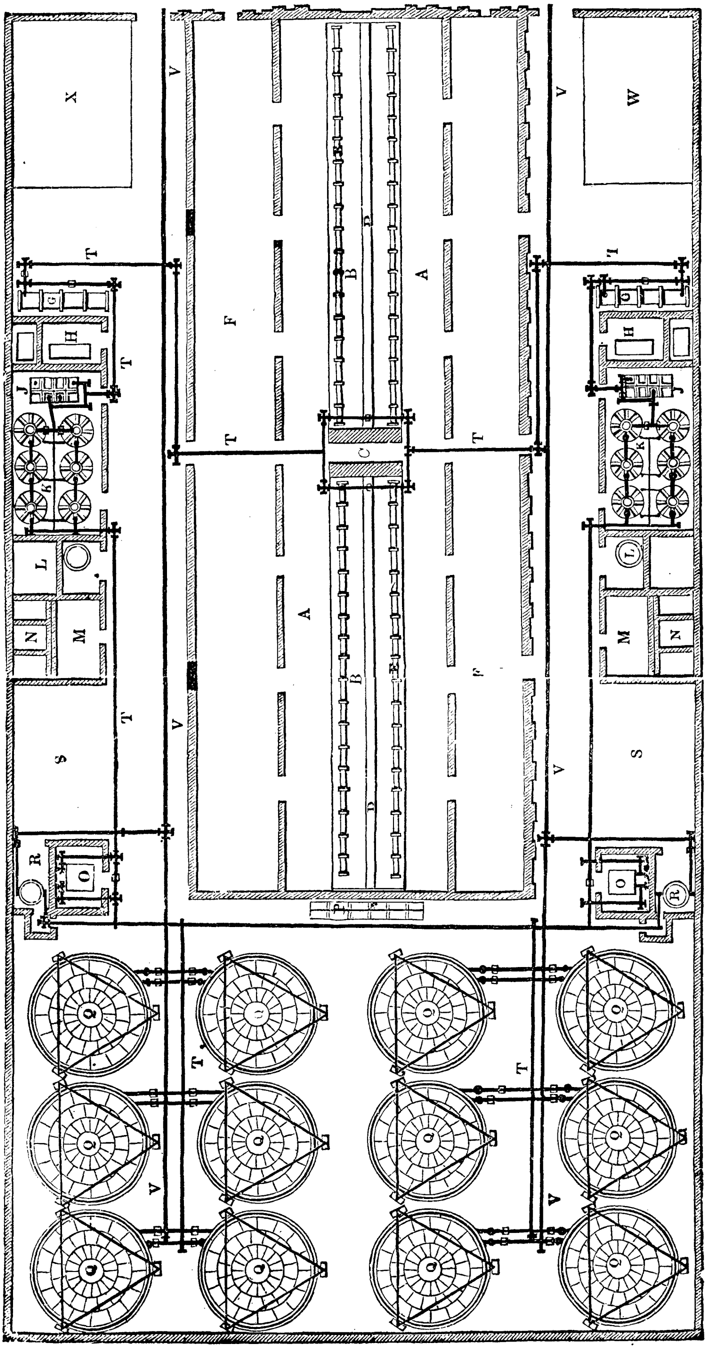

Fig. 693. End elevation and plan of air condenser; A, end elevation; B, plan.

Fig. 694. Set of 3 wet-lime purifiers and wash-vessels in elevation and section, with feed-heads, agitators, valves, and connections, raised for the lime liquor to run from one purifier to the next below it, and ultimately into the refuse lime-pits, viz. A, section of wash-vessel; B, section of purifier; C, elevation of purifier.

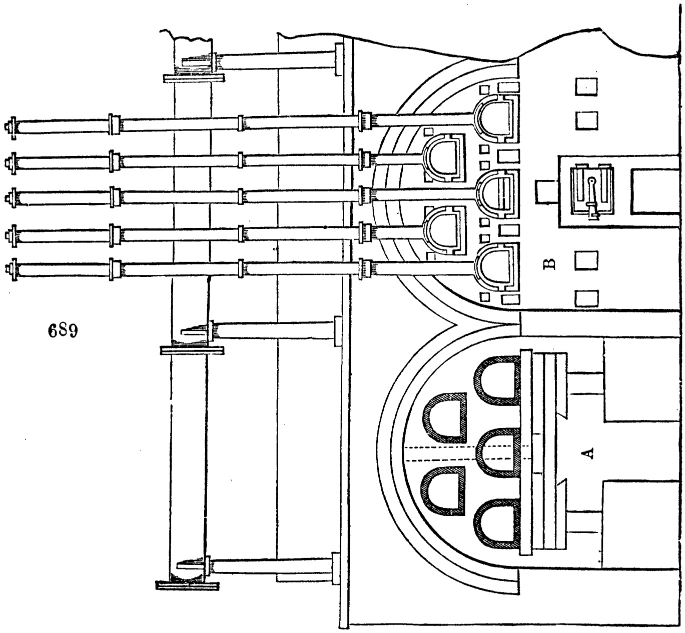

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Fig. 695 Front elevation of gas works on a smaller scale, where dry lime is used.

Fig. 696. Plan of gas works, consisting of, viz.: A, retort house; B, retort beds; C, chimney stack; D, flue; E, hydraulic main; F, coal store; G, lime store; H, washer and purifiers; J, store; K, tar-tank; L, horizontal condenser laid on the ground; M, inlet pipe; N, outlet pipe; O, tanks and gas-holders; P, meter and governor; Q, smith's shop; R, office; S, coke store.

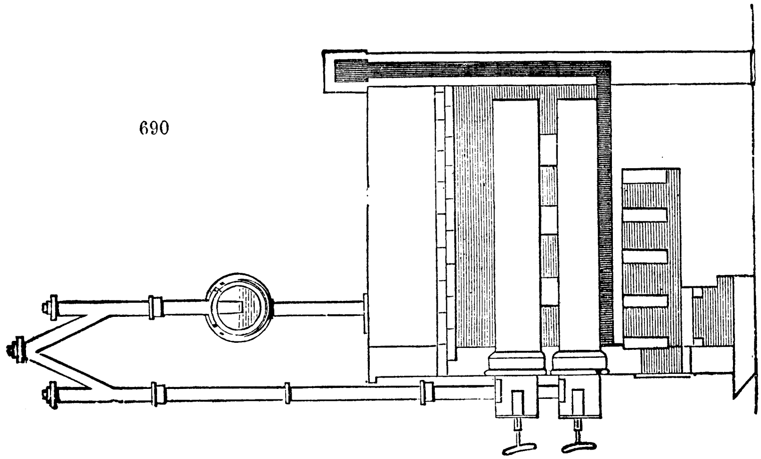

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Fig. 697. Elevations and sections of dry-lime purifiers; A, longitudinal elevation; B ditto section; C, transverse elevation; D, ditto section.

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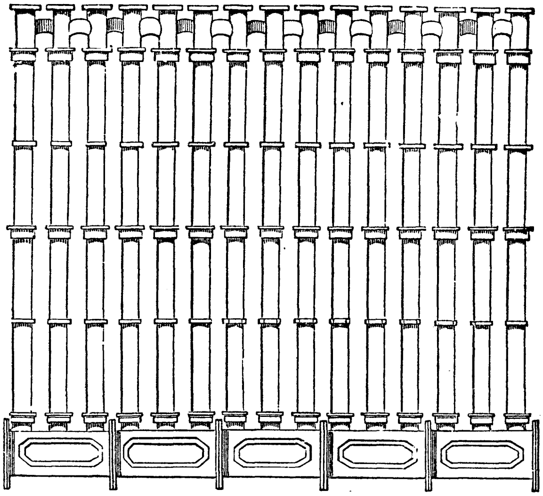

I am well convinced that a distribution and arrangement of gas-works, combining effectiveness, economy, convenience, and elegance, at all equal to the preceding, have never before met the public eye, in this or any other country.

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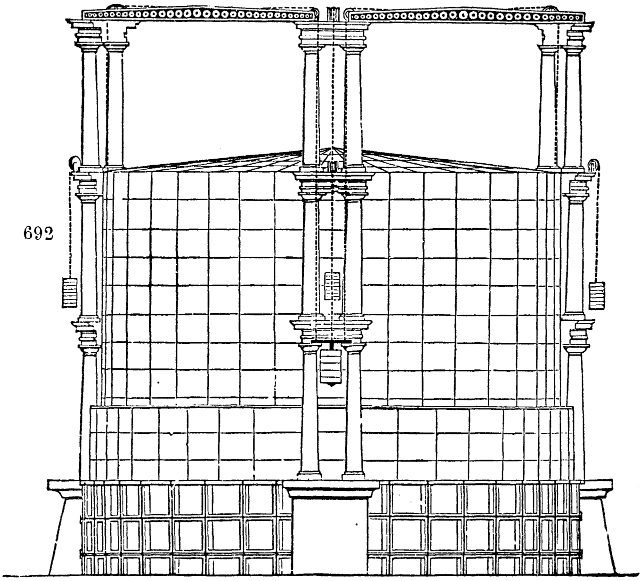

In the brief description of the meter given in this Dictionary, I omitted to state, that this most ingenious scientific contrivance for measuring aeriform or gaseous fluids as they flow through pipes is the invention of Samuel Clegg, Esq., Civil Engineer, of

London, Manchester, Liverpool, Birmingham, Chester, Bristol, &c. &c., in all which places he has erected gas-works. To this gentleman's genius and skill the public are mainly indebted for many valuable improvements in the application of gas from coal to purposes of illumination.

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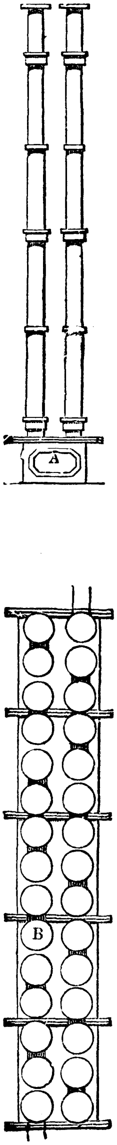

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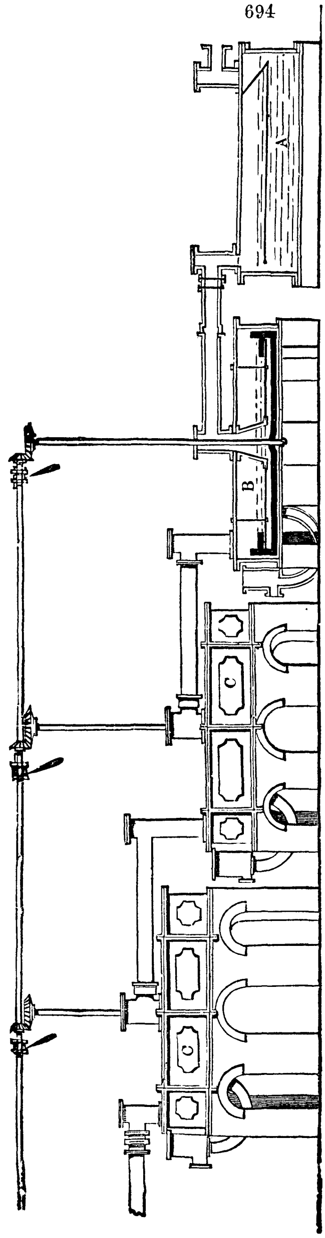

Brought up in the great engineering establishment of Messrs Boulton and Watt, at Soho, near Birmingham, he became connected with Mr. Wm. Murdoch, who most undoubtedly was the author and originator of gas-lighting, as the evidence given before a Committee of the House of Commons in the year 1809 abundantly verified. He

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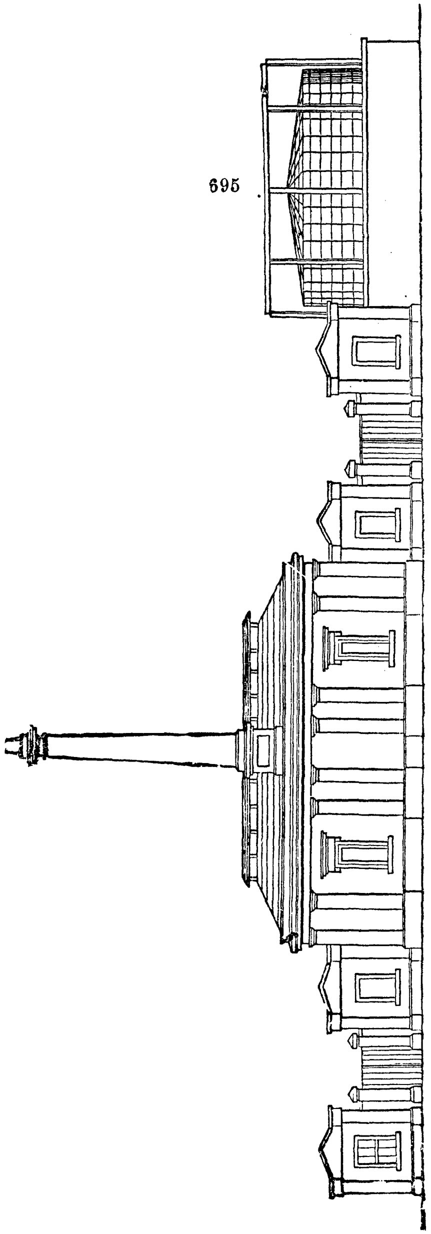
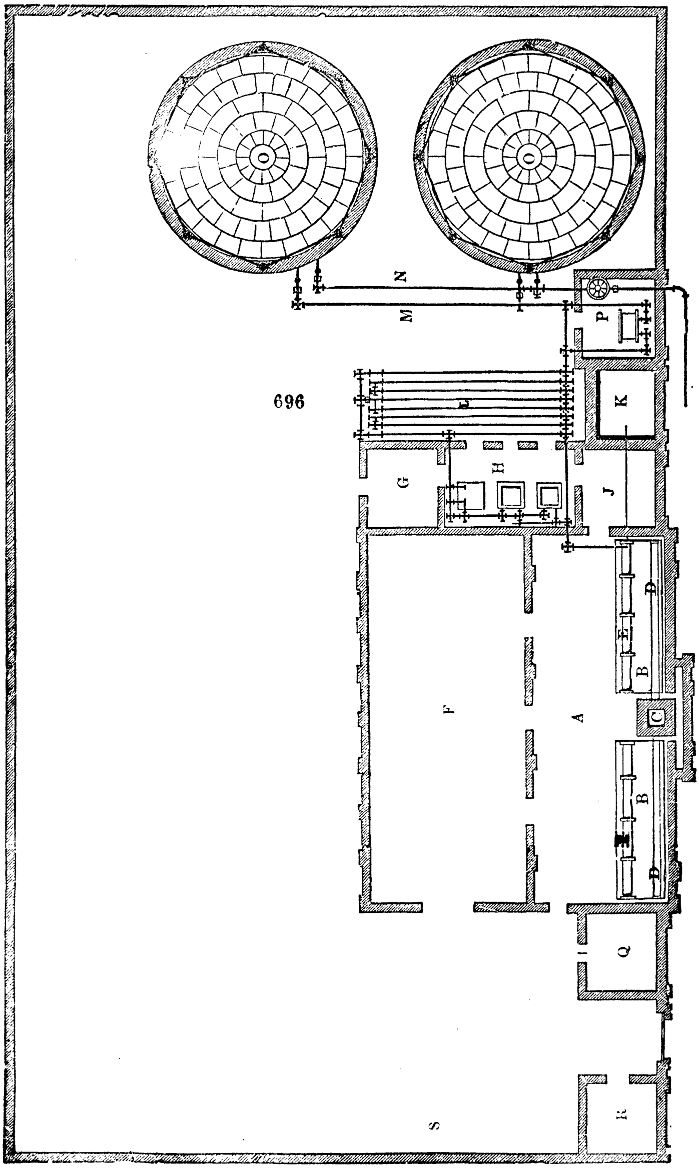


demonstrated that the light produced from gas was superior in economy to all other modes of artificial illumination; and by that evidence, though so long back as 1809, it will be seen that all the information of the present day was even then known to him, clearly pointed out, and illustrated by his experiments, which strangely contrasted



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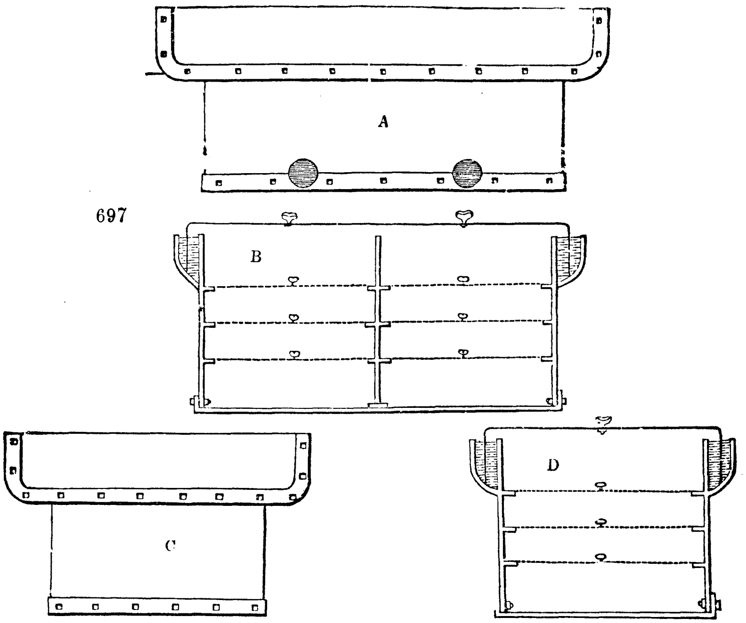

with the statements put forward by the parties then attempting to introduce this mode of lighting into the metropolis. All the ephemeral plans of those parties, have, however, long since disappeared, or nearly all. One, unfortunately, remains, and that a most unlucky one—the unprofitable manufacture of coke in gas-making—an article worthless in the scale of value, which should never have been sought for. Messrs. Watt and Murdoch predicted that when the parties became incorporated by Parliament, they would resort to *their* apparatus, notwithstanding their repudiation of it at the time, alleging their own schemes to be so much superior; and they verified this prediction a very few years afterwards by engaging the services of Mr. Clegg, to extricate them from their manifold and egregious errors. He began by introducing the very apparatus of Messrs. Murdoch and Watt, so inconsiderately condemned by them.

Mr. Clegg put up the *first* gas-holder ever erected in London.

To Mr. Clegg is due also the introduction of lime for the purification of the gas, without which gas-lighting would to this day have afforded little comfort and economy. The hydraulic main, for separating the gas *making* from the gas *made*, valves, lutes, and many other admirable contrivances, are peculiarly due to Mr. Clegg. But the crowning performance of all his inventions, was that for measuring out the gas to the several parties requiring it exactly according to their demands. The manufacture of gas having by this time been so far mechanically perfected as to be brought to our doors, it became at once apparent that some contrivance should be found by the use of which every person might consume as much or as little gas as he pleased, paying only for what he really used, thus making science subservient to fair dealing.

Mr. Clegg took out a patent for the gas meter about the year 1814; but great as its merits were, he soon found that serious difficulties remained to be overcome, in inducing parties to support and encourage its use, even where their interests should have prompted them to adopt it. Mr. Clegg had, however, fortunately associated with him, towards the completion of the apparatus, Mr. Samuel Crosley; and by their joint labours it acquired its present precision.

The value of the meter is *primarily* to the gas companies, *next* to the public. By its use, the gas companies are enabled to supply gas to all places where light is required, at a rate proportioned to its just value. The public thereby see the economy afforded by gas over candles, oil, or other material; but they gain also in another most important way—by the use of the meter, gas companies, being duly paid, are enabled to *reduce* the *price of gas*, and *yet realise equal profits*, thus bringing it within the reach of a much larger class of the community; and it is a well established fact that in towns where gas is sold by meter, gas companies can and do sell at nearly one half the price they otherwise could do.

Reduction of price increases demand; increased demand increases profits; increased profits again enable prices to be reduced; and again, reduced prices increase the demand thus benefiting reciprocally companies and consumers.

Notwithstanding, however, all these advantages, there are not wanting persons who have set up an outcry against the use of the meter, by impugning its accuracy, and accusing the gas companies with fraud in charging by it. It would be idle to follow these parties in their baseless allegations. An action for pirating it was brought and tried in the Court of King's Bench, in which not only the novelty of the machine was fully established, but its accuracy and usefulness proved by the ablest mathematicians, mechanicians, and chemists of the day; and a verdict in its favour obtained. Subsequently very large damages have been given for the infringement—in one case as much as 5000*l.*, and in another, in the Court of Chancery, a decree was made referring it to the Master, to take an account of the profits made by the use of the meter; this is not yet finally settled, the Master's report finding 6000*l.* to be due; but this is excepted to by the parties infringing: the Chancellor, however, allowed the exceptions to be argued, only on payment by the infringers of 4000*l.* into court to meet the patentee's law costs. These exceptions have no reference whatever to the question of the accuracy of the meter, but are simply as to whether the advantages of the meter were as great as allowed by the Master.

The patent for the meter expired about the year 1828; since that period numerous competitors have commenced making the machine.

Mr. Clegg has recently obtained a patent for a *dry* gas-meter, of which the following are its advantages and construction, as described by the very meritorious inventor:—

1. Working without water.
2. Working without membranes or valves.
3. Working without requiring the least pressure.
4. Working without interference with the perfect steadiness of the lights.
5. Registering more accurately than any other meter.
6. Occupying only one-tenth of the space of the common meters.
7. Being subject to little or no wear and tear.
8. And being cheaper.

Prices.—For plain meters.—

	£	s.	d.
Three-light meter	1	12	0
Six-light do.	2	4	0
Twelve-light do.	3	3	0

The highest numbers will be still cheaper in proportion.

Ornamental meters, appearing like handsome time pieces, for halls, living-rooms, committee-rooms, offices, counting-houses, &c., are charged extra, at *ten shillings each* and upwards, according to pattern.

Description of Clegg's patent dry Gas-meter.

The two *figs.* 698,9. are half the full size of the apparatus, and the letters of reference are the same in both.

B, B, *fig.* 698., represents a cylindrical vessel, about three inches and three quarters diameter, and four inches deep, being the dimensions of a meter capable of measuring gas for three burners, called a three-light meter. In this vessel are two glass cylinders F, F, connected together by the bent tube *d.* The cylinders being perfectly exhausted of air, and half filled with alcohol, are made to vibrate on centres *e* and *e*, and are balanced by the weight *f.*

This instrument accurately indicates the excess of heat to which either cylinder may be exposed, upon the principle of Leslie's differential thermometer.

C is a hollow brass box, called the heater, about four inches long, and half an inch broad, projecting out of the meter about one inch. At *a* issues a small jet of gas, which, when inflamed, gives motion to the cylinders.

The gas enters the meter by the pipe A, and circulates throughout the double case B: having passed round the case B, a portion of it enters the top of the box C, by the pipe D, and passes out again at the bottom by the tube *c*, into the meter; the rest of the gas enters the body of the meter through holes in the curved faces of the hoods EE, and, after blowing on the glass cylinders, passes to the burners by the outlet pipe.

To put the meter in action, let the jet *a* be lighted about an hour before the burners are wanted. In most cases this jet will be lighted all day as a useful flame. The hole *a* is so situated on the box C, that whatever be the size of the jet, a fixed temperature is given to the box, that temperature depending on the quantity of flame in

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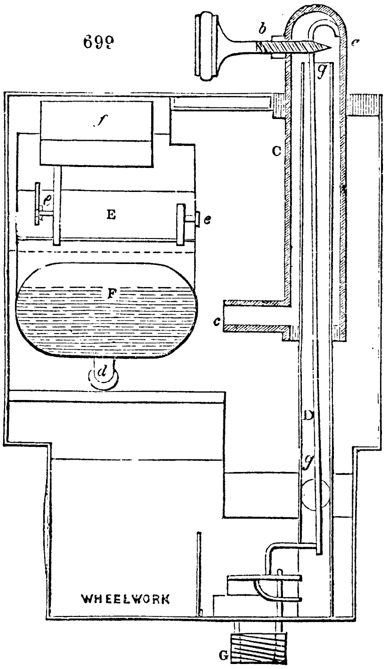

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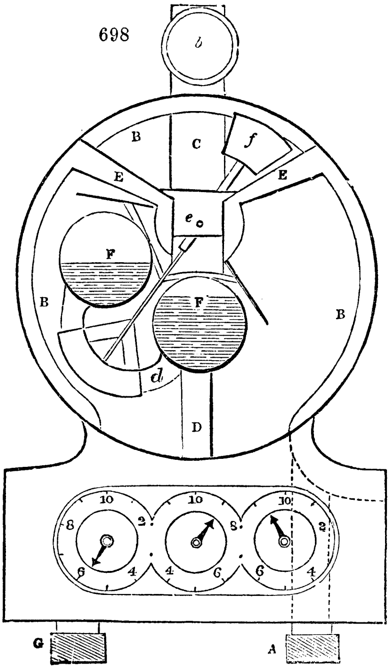


contact with the box, and not at all on the length of the jet. The jet being lighted, and the box C thereby heated, the gas which passes through it is raised to the same temperature, and, flowing out at the tube *c*, impinges on the glass cylinder which happens for the time to be lowest; the heated gas soon raises a vapor in the lower cylinder, the expansion of which drives the liquid into the upper one, until it becomes heavier than the counterpoise *f*, when the cylinders swing on their centre, the higher one descends, and comes in the line of the current of hot gas, and the lower one ascends; the same motion continues as long as the jet *a* burns. The same effect on the cylinder is maintained, however the outward temperature may change, by the cold gas, which, issuing from the curved side of the hood EE, impinges on the upper cylinder, and hastens the condensation of the vapor which it contains.

The cold gas and the heater vary in temperature with the room, and thus counteract each other.

The lighting of the jet *a* is essential to the action of the meters; in order to insure this, the supply of gas to the burners is made to depend on it in the following manner. The pipe G, by which the gas leaves the meter, is covered by a slide valve, which is opened and shut by the action of the pyrometer *g*; the pyrometer is in communication with and receives heat from the jet, and opens the valve when hot, closing it again when cold.

The speed at which the cylinders vibrate is an index of the quantity of heat communicated to them, and is in exact proportion to the quantity of gas blowing on them through the pipe *c* and curved side of the hoods EE.

The gas passed through the heater is a fixed proportion of the whole gas passing the meter; therefore the number of vibrations of the cylinders is in proportion to the gas consumed.

A train of wheel-work, with dials similar to that used in the common meter, registers the vibrations.

Simplicity, accuracy, and compactness, are the most remarkable features of this instrument, and the absence of all corrosive agents will insure its durability.

Directions for fixing and using Clegg's patent dry Gas-meters.

Choose a situation for fixing the meter, where the small jet of flame will be of the greatest use, such as an office-desk or counter, taking care to screw the same firm and level on its base. When the jet at the top of the meter is required to be kept constantly burning as a useful flame, press in the brass knob at the front of the meter, and before lighting the burners pull it out; when the small flame is not required, let it be lighted about an hour before you want the burners lighted. Adjust the size of the small flame at pleasure by the screw *b*.

On the back of each meter is marked the number of lights it will supply.

The inlet and outlet pipes are marked at the bottom of the meter.

The quantity of gas consumed is recorded by the index in the usual way.

For testing Clegg's patent dry Gas-meters.

Pass the gas through two meters at least, and take the mean. Vary the number of lights at pleasure, not exceeding the number marked on the meter, and when one or two hundred cubic feet of gas have been consumed, compare the indices.

These meters are not for measuring small fractional parts; but taking the average for any periodical consumption, are more accurate than any other meter.

Mr. Thomas Edge, of Great Peter Street, Westminster, has contrived the following meter, of which drawings are annexed.

Fig. 700 is a front view of a three-light meter, the front plate being removed, and some of the parts shown in section 65.

700

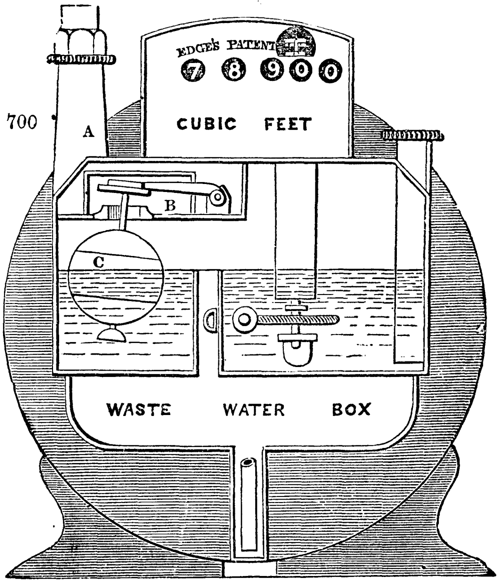
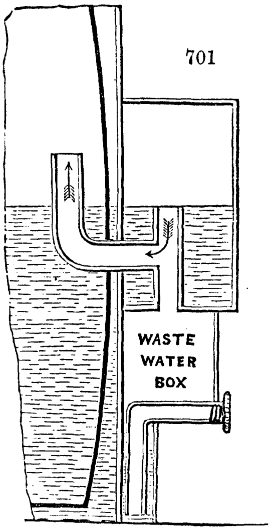


Fig. 701 is a transverse section of the same.

The gas enters at A into the small chamber B, in the bottom of which is a lever valve (part of Mr. Edge's patent improvements), moving upon its axis and attached by the rod to a metal float C, which in the present drawing is buoyant. The object of this arrangement is to intercept the passage of the gas into the meter, unless a sufficient quantity of water is in it, that being necessary to its proper action; the gas then passes through the inverted syphon or tunnel into the convex cover, whence it passes into the chambers of the drum.

Another of Mr. Edge's improvements consists in the cutting down of this syphon pipe or tunnel to the proper water level, and connecting the bottom of it to a waste water-box, into which any surplus water must fall. The importance of this precaution will be seen on investigating the drum, as an excessive height of the water will materially interfere with the measurement, the quantity of gas delivered per revolution being considerably less. This, in connexion with the lever valve and float, confines the variation of the water levels within such narrow limits, that the measurement may be considered perfectly just on all occasions.



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The last patent by Mr. Edge is for an improved index, which is composed of a series of moving dials, with 10 figures upon each, one figure only appearing of each series at a time.

This contrivance is very ingenious, and will no doubt be applied to other machines, where indexes (*indices*) of quantity are required.

Recurring to Mr. Clegg, he is also the inventor of an instrument of great value—appropriately called a "governor." Its purpose is to render equal the height of flame of the several burners in any house or establishment, and to keep them so, notwithstanding any, and whatever alteration may be made in the pressure at the works or elsewhere. This instrument is perfected, and successfully applied, though it is not so generally in use as it ought to be. By the use of this instrument a light once set at the height desired will maintain that height uniformly, and without the least variation the whole evening; and continue to do so till altered.

Without this instrument, it is necessary to pay attention to the burning of gas-lights, as their heights are frequently affected by the most trifling circumstance, such, for example, as their extinction at the hour of closing the shops, which makes a sensible difference in the neighborhood.

All these works have prodigiously increased in the quantity of gas made and supplied. Since the account in the former edition of this work, large additional manufactories have been erected by new companies, and great additions made by the old ones. There are now in the metropolis alone 15 public gas companies, having among them 23 gas establishments. The quantity of gas manufactured by these 23 gas-works, and supplied to the public was during the past year three thousand one hundred millions of cubic feet of gas; and the coal used to produce this quantity of gas was at the least 400,000 tons!

Baked clay retorts are very generally used in Scotland, and found to be most economical as regards wear and tear; in London, however, they are mostly of cast iron.

The pressure upon the retorts is caused principally by the use of *wet lime*, used in London, because the process is less expensive and less cumbersome than dry lime. Wet lime can not be used with clay retorts, owing to this excess of pressure.

Merit is due, for enlarging the capacities of double gas-holders, to the late Mr. Joshua Horton, of West Bromwich, near Birmingham; and to Mr. Stephen Hutchinson, engineer of the New London Gas-Works, Vauxhall, where they were first successfully introduced, and manufactured by Mr. Horton. They have now come very generally into use throughout the kingdom, and are manufactured by all gas-holder makers.

Separate gas-holders are advisable and advantageous, but they are not generally used, except in Glasgow, Manchester, Birmingham, Sheffield, and a few other places.

The annexed drawing represents Mr. Croll's vessels for the purification of gas from ammonia, which is effected by means of dilute sulphuric acid applied between the condensers with the ordinary lime purifiers. The vessels are made of either wood or iron, and lined with lead; have a wash-plate similar to the wet lime purifiers. The radiating bottom formed of wooden bars, as shown in the drawing, is for the purpose of supporting the wash-plate and distributing the gas.

Fig. 702: *a*, is the inlet pipe; *b*, the outlet pipe; *c*, *c*, the tube with funnel for introducing the sulphuric acid; *d*, the first purifying vat; *e*, the second ditto, both lined with lead, and which are filled up to the dotted line with the dilute acid; *f*, *f*, the water supply-pipe; *g*, *g*, the discharging cocks.

Fig. 703 represents a ground-plan of the vats, each 10 feet in diameter; A, the bottom of the middle; B, the inlet of the gas; C, the outlet of ditto.

In commencing the process, these vessels are charged with water and sulphuric acid, in the proportion of seven pounds, or thereabouts, of the latter, to 100 gallons of the former. As the acid is neutralized by the ammonia contained in the gas passing through the vessels, the above proportion, as near as may be, is kept up by a continuous dropping or running of acid, regulated according to the quantity of ammonia contained in the gas, from a reservoir placed on the top of the saturator. This mode of supplying the acid is continued until the specific gravity of the solution arrives at 11˜0, or close

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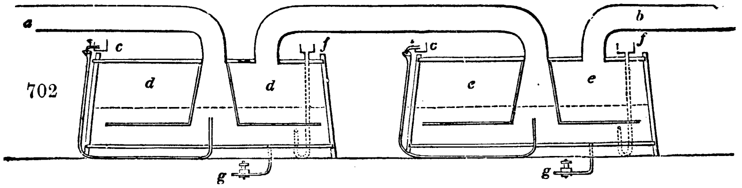

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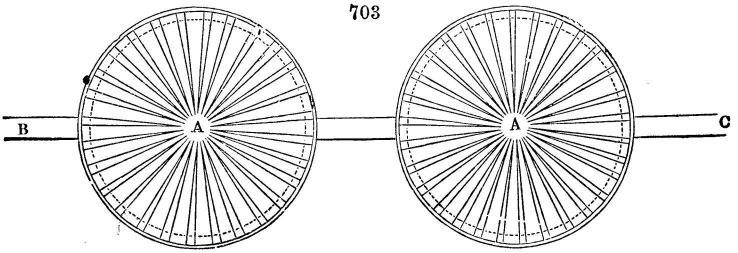

to the point of crystallization, after which the supply of acid is discontinued, and the liquor retained in the vessel until neutral, when it is drawn off and evaporated, and yields a pure sulphate of ammonia.

This process has been introduced at several of the provincial gas-works, the three stations of the Chartered, the Imperial, Phœnix, &c., &c. Mr. Croll is also now in treaty with several other companies for its introduction.

The produce—sulphate of ammonia—from the process, by the gas-companies using it, now amounts to several tons per week—and it may be here mentioned, as one of the advantages of science, that the ammonia so produced before the adoption of this process passed along with the gas to the consumer, destroying rapidly the main pipes, fittings, and metres, through which it was transmitted, as well as deteriorating the illuminating power of the gas, and producing a choky effect when consumed in close apartments. It is now employed as a manure, and found to be superior in its effects as a fertilizer, as well as comparatively cheaper than any of the other artificial manures; so that whether Mr. C.'s invention be looked upon as affecting improvements in the manufacture of gas, hitherto unknown, or as producing a valuable manure, the results are alike of the utmost importance.

(When Mr. Croll's process is employed before the lime purifiers, dry lime can be used without creating the nuisance hitherto complained of, and a much less quantity is required for this purification.)

Mr. Croll has recently patented another invention, connected also with the manufacture of gas, which consists in the combination of clay and iron retorts, so that the heat of the furnace first acts on the clay retorts and then passes to those of iron.

The annexed drawing is a transverse section ·—

A is the fireplace.

B B are piers of fire-bricks, placed at intervals to form nostrils or flues, and the fire tile resting upon them in conjunction with the front and back wall, form the bed or support of the clay retort 1, and the clay retort 2 is also supported by the front and back brickwork, and a lump, or fire-brick, E, placed midway on the crown of the retort 1.

F is a wall which separates the clay retorts 1 and 2, and the iron retorts 1° and 2°; a space being left between the top of the said wall F, and the under surface of the arch, to allow the fire or heated air to pass freely from the clay to the iron retorts.

G G is the bed, and H H is the flue under the iron retort 1°. The retort 2° is supported by the front wall and pieces or lumps.

J, placed at the back and crown of the retort 1°, in connexion with the horizontal flue. H is a vertical flue, forming a passage thence into the shaft or chimney.

The heat passes from the furnace or fireplace A, through the spaces or nostrils formed by the piers B B, and around the clay retorts 1 and 2, over the wall F, descends between and around the iron retorts and along the flue H, and escapes by the vertical flue into the chimney. The advantages of this mode of settin retorts are the small quantity of brickwork necessary for the erections, the increased durability of the retorts, and the economy in fuel. From adopting this mode of setting a brick lump, it has been found that 12 tons of coke will carbonize 100 tons of coal.

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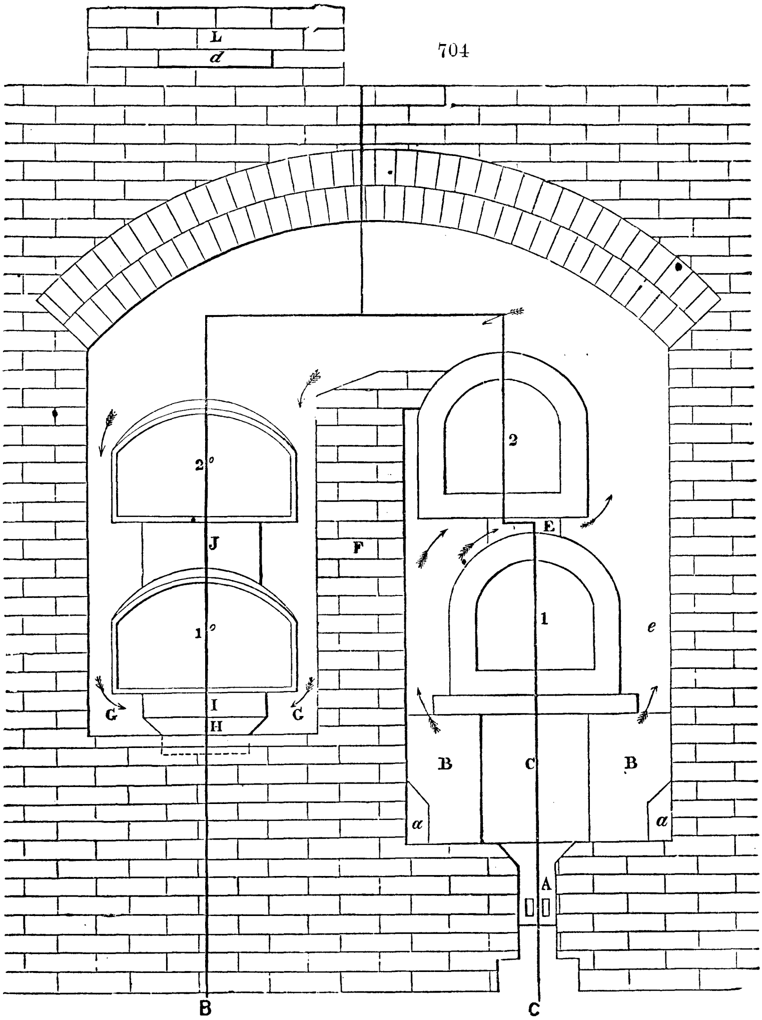

L is the chimney stalk, and *d* is a damper or register plate for regulating the chimney draught.

Before dismissing Mr. Croll's patent improvements, it is proper to state, that the sulphuric acid used for condensing the ammonia should be free from iron, otherwise the sulphuretted hydrogen of the coal gas is apt to give rise to sulphuret of that metal which will blacken the sulphate of ammonia and reduce its value in the market. An occurrence of this kind was recently brought professionally before me for investigation. The sulphuric acid had been made from pyrites.

Mr. Kirkham, engineer, obtained a patent, in June, 1837, for an improved mode of removing the carbonaceous incrustation from the internal surfaces of gas retorts. He employs a jet or jets of heated atmospheric air or other gases containing oxygen, which he impels with force into the interior of such retorts as have become incrusted in consequence of the decomposition of the coal. The retort is to be kept thoroughly red hot during the application of the proposed jets. An iron pipe, constructed with several flexible joints, leading from a blowing machine, is bent in such a way as to allow its nozzle end to be introduced within the retort, and directed to any point of its surface.

I should suppose that air, even at common temperatures, applied to a retort ignited to the pitch of making gas, would burn away the incrustations; but hot air will, no doubt, be more powerful.

Bude-light. — This brilliant mode of illumination has been so called from the name of the residence in Cornwall of Mr. Goldsworthy Gurney, who obtained a patent for it in the year 1838. In its first form it consisted of a common Argand oil flame or lamp of rather narrow circular bore, into the centre of whose wick a jet of oxygen gas was admitted through a tube inserted in the middle of the burner. This contrivance was not, however, new in this country, for a similar lamp, similarly supplied with oxygen gas, was employed by the celebrated Dr. Thomas Young in his lectures at the Royal Institution of Great Britain for the purpose of illuminating a solar microscope, or gas microscope, about 40 years ago, and I had done the same thing in Glasgow in the year 1806 or 1807. When used as a light for lighthouses or for other continuous illumination, it has been found to be too expensive and difficult to manage. It was tried upon a good scale a few years ago both by the Trinity House in Tower Hill, and in one of their lighthouses on the coast, as well as by the House of Commons. The Masters of the Trinity did not find it to be essentially superior for the use of their lighthouses to their old and ordinary plan of illumination with a number of Argand lamps placed in the focus, or near the focus, of reflecting mirrors. It was, after several expensive trials by them, and in the House of Commons, abandoned by both.

In the course of numerous experiments in the Trinity House, Tower Hill, Mr. Gurney had occasion to examine the structure and see the performance of Mr. Fresnel's compound Argand lamps which are used in the French lighthouses, furnished with refracting lenses of peculiar forms which surround these lamps, and transmit their concentrated light in any desired horizontal direction along the surface of the sea. Two of Mr. Fresnel's lamps are placed in the lamp apartment of the Trinity House. Each consists of a series of 4, 5, or 6 concentric wicks in the same plane, supplied with oil from the fountain below by means of a pumping mechanism, as in the well-known Parisian lamps of Carcel and Gagneau. The effect of 4, 5, or 6 concentric flames thus placed in close proximity to each other, with suitable supply of air through the interior of the innermost tube and the interstices between the exterior ones, is, to increase the heat in a very remarkable degree, and by this augmentation of the heat to increase proportionably the light. For it has been long known that a piece of even incombustible matter, such as a lump of brick, intensely heated, sends forth a most brilliant irradiation of light. This fact was applied first to the purpose of illuminating objects by Professor Hare, of Philadelphia, fully 40 years ago. By directing the very feebly luminous flame of the compound jet of hydrogen and oxygen upon a bit of clay, such as one of Wedgwood's pyrometer pieces, a most vivid illumination was sent forth from it as soon as it became intensely heated. More lately, a piece of lime has been used instead of a bit of clay, as it is not so apt to change by the ignition, and affords, therefore, a more durable effect. It is used in our modern gas microscopes. Mr. Gurney suggested the use of lime for the above purpose in a work on chemistry which he published more than twenty years ago. It was afterwards adopted by Mr. Drummond, in order to make signal lights in the trigonometrical survey of the Board of Ordinance, and was therefore called the Drummond light, though he had no share whatever in the merit of the invention.

The structure of the Fresnel lamp would naturally suggest to Mr. Gurney the idea of trying the effect of a similar construction of an Argand gas lamp. But prior to the execution of this scheme, he obtained a second patent in the year 1839, for increasing the illuminating power of coal gas by feeding its flame in a common Argand burner with a stream of oxygen. But here a serious difficulty occurred. The stream of oxygen, when admitted into the centre of such a flame, instead of augmenting its quantity of light, destroys it almost entirely. This result might have been predicted by a person well versant in the principles of gas illumination, as long ago expounded in Sir Humphry Davy's admirable Researches on Flame. This philosopher demonstrated that the white light of gas-lamps, as also of oil lamps, was due to the vivid ignition of solid particles of carbon evolved by the igneous decomposition of the hydro-carburet, either in the state of gas or vapour; and that if, by any means, these particles were not deposited, but burned more or less completely in the moment or act of their evolution from the hydro-carburet, then the illumination would be more or less impaired. Mr. Gurney, on observing this result, sought to obviate the evil, by charging the coal gas with the vapour of naphtha. Thus a larger supply of hydro-carbaret, and of carbon of course, being obtained, the flame of the naphthalized gas, admitted with advantage the application of oxygen gas, for the increase of its light; on the principle of greater intensity of ignition, and consequently of light, being produced by the burning of carbon in oxygen than in common air, as had been long known to the chemical world. But an obstruction to the permanent employment of naphthalized gas was experienced by Mr. Gurney, from the deposition of liquid naphtha in the pipes of distribution. He was therefore induced to renounce this project. He then resorted to the use of coal-gas, purified in a peculiar way, and burned in compound Argand lamps, consisting of two or more concentric metallic rings, perforated with rows of holes in their upper surfaces, having intervals between the rings for the admission of a proper quantity of air, the burner being enclosed in a glass chimney at the level of the flame, surmounted by a tall iron chimney. Between these two chimneys, a certain space is left for the admission of air, and to favour draught and ventilation. The intensity and whiteness of the cylinder of light produced by the combustion of coal-gas in this lamp are truly admirable, and form such an improvement in illumination for streets, churches, public rooms and private houses, as to merit the protection of a patent, and the encouragement of the public at large.

General Estimate of Sizes, Number of Concentrics, Consumption of Gas, and Comparative Light.

Size.	Number of Concentrics.	Bude Consumption per hour.		Height of Flame.	Comparative Light.	Argand Consumption per hour.
Inches.		Feet.	Inches.	Inches.	15-hole Argands.	Cubic Feet.
2½	2	10	6	3	5	30
3	2	16	4	3	8	48
3½	2	21	6	3	10	60
4	2	26	4	3	12	72
4½	2	33	7	3	15	90
5	3	40	0	3¼	18	108
5½	3	43	5	3½	20	120
6	3	56	4	4	24	144

Laming and Evans's Invention.—The first part of this invention consists of an improvement in retorts for making gas, and for other uses; and in making pots, crucibles, muffles, stoves, fire-bricks and lumps, and other articles of clay, required to stand the action of fire without cracking. The improvement consists in mixing with the fire-clay, which is to enter into the composition of any of the aforesaid articles, about 0·25 per cent. of its weight of asbestos or fibrous silicate of magnesia; the vessels are then to be constructed and burned in the usual manner. The patentees state that they do not confine themselves to any particular forms of the articles, each of which may be made of one or more pieces, as at present; and the proportion of silicate of magnesia may be varied to meet the exigencies of particular cases, its introduction being for the purpose of giving greater tenacity to the materials used, and thus diminishing their tendency to become cracked under the influence of change of temperature.

They claim under this head of the invention, the introduction of asbestos or fibrous silicate of magnesia among the materials used for making articles of clay, intended to be submitted to a great heat; and the use of all such articles, made with asbestos or fibrous silicate of magnesia in their composition.

Another part of this invention consists in an arrangement of apparatus for making gas from oil, tar, melted pitch, resin, fat, or other analogous material, in conjunction or not with water. The apparatus consists of an iron or clay retort, composed of two horizontal chambers, one above the other, and communicating at the back only. The ends of the chambers are closed by three man-hole doors; two of which are secured over the front end of the chambers; and the third, which is a large door, serves to close the hind ends of both chambers;—the three doors all projecting beyond the brickwork setting of the retort. Upon the upper chamber, near the front end thereof, is an inverted funnel of large diameter, closed by a cover, the edge of which is turned down, and dips into a hydraulic joint, or into a joint filled with metal, fusible at the temperature to which it is exposed, or else it is secured in the same manner as the ordinary man-hole doors. The cover is fitted with a double syphon, furnished with a stop-cock. The eduction-pipe, leading to the hydraulic main, is connected with the front end of the lower chamber of the retort. To use this apparatus, previously raised to the usual temperature, the patentees charge the upper chamber with coke, heaping it somewhat just beneath the funnel, and allowing some pieces to fall over against the large man-hole door at the back, and they charge the lower chamber either with coal or coke. A stream of oil, tar, melted pitch, resin, fat, or other analogous matter, in conjunction or not with water, is then allowed to fall from the double syphon through the large funnel, on to the red-hot coke beneath; it passes thence, partly as gas and partly as liquid, through the upper chamber to the back of the lower one, along which it next proceeds, chiefly in the state of gas, and escapes, mixed with the gaseous products of the lower chamber, through the eduction pipe into the hydraulic main. When the lower chamber of this apparatus is charged with coal, the liquid should not be permitted to flow from the double syphon, till the coal has had time to give off the greater part of its richer gas, and to become heated throughout; but when coke is used in both chambers, the liquid is admitted from the commencement, and without intermission, until the passages of the gas apparatus need to be opened and cleaned out.

The patentees do not claim the making of gas from tar, or any other form of hydro-carbon, or water, by means of red-hot coke, or the combining of any materials affording gas. What they claim is, the combination and arrangement of the apparatus, particularly of the large funnel, with the double chambers, and back and front man-hole doors, for making gas by the decomposition of any suitable hydro-carbon, or water, by bringing it, in a fluid state, into contact with red-hot coke or other suitable material.

Another part of the invention consists in elongating the eduction pipes of retorts, used for making gas for illumination, into their interior, and arranging them in lines near their axes. The further ends of these pipes are left open, and they are supported by bearers. Holes should be made along the pipes, but only in sufficient number to permit of the free escape of the gas as it is generated; or a longitudinal slit may be made in the under side of the horizontal pipe, from its further end to near its ascending portion; and this arrangement is preferred, because it admits of the passage being cleared out by a proper tool, in the event of its becoming choked. The improvement is applicable to retorts of any material, and of the ordinary forms; but it will be found more easy to charge the retorts, to which this improvement is applied, when they are made large enough to receive a charging-scoop on either side of the horizontal eduction pipes. The object of the improvement is to diminish the contact of a gas with a surface heated high enough to cause it to deposit some portion of its carbon; and thus to produce a richer gas, or a larger quantity of equally rich gas, from a given quantity of coal.

The claim made under this head is for the elongation of the eduction-pipes of retorts, used for making gas for illumination, along or near their axes.

Another part of the invention consists in a process for obtaining light by means of platinum, heated to whiteness by coal gas or peat gas. It is known, that when water is decomposed, and the resulting hydrogen burnt within a small cage, made of platinum wire or platinum foil, in such a manner as to heat the metal to whiteness, the platinum becomes luminous, and remains so as long as its temperature is maintained; but it is equally well known that hydrogen gas, resulting from the decomposition of water, is not readily obtainable under the generality of circumstances when light is required. The improvement consists in replacing hydrogen gas from water by coal gas (which is to be obtained almost universally, and which answers the purpose) or by peat gas. In carrying out this improvement, it is preferred to burn the gas either by itself, or mixed with atmospheric air, within a platinum wire cylinder, greater in height and diameter and made of coarser material, as the quantity of gas burned within it in a given time is greater,—the only practical rule that it is necessary to give being, that all the metal be placed, with respect to the flame, in the best position for becoming white-hot. The advantages which result from this part of the invention are, first, with respect to ordinary coal gas, that more light is obtained in proportion to the quantity of coal gas consumed, than is the case when platinum is not used; and, secondly, that, by its means, a good light is obtained by the combustion of peat gas, or of coal gas of inferior quality.

Under this head, the patentees state, that they neither claim nor restrict themselves to the use of any particular form or dimensions of the platinum apparatus; but what they claim is, the use of coal or peat gas, mixed or not with air, for heating platinum wire or foil to whiteness, and thereby producing light.

A previous patent has been obtained by one of the patentees (Mr. Laming), for purifying coal gas by a solution of muriate of iron, mixed with porous materials; and also by muriate of iron, decomposed by lime into chloride of calcium and oxide of iron, and made porous by suitable materials. Now, one part of the present invention consists in combining known processes, so as to obtain the last-named purifying materials. The patentees decompose sulphate of iron, in solution, by its equivalent quantity of chloride of sodium; and, having separated, by known means, the resulting sulphate of soda, they add to the solution of muriate of iron concentrated by evaporation, first, enough dry sawdust, or other suitable matter, to absorb it, and then enough hydrate of lime to decompose it into chloride of calcium and precipitated oxide of iron. Coal gas is purified with this mixture, disposed in dry purifiers; and, afterwards, sulphur, cyanogen, and muriate of ammonia, are extracted from the used materials by any ordinary processes adapted for that purpose. Sometimes the purifying material is modified in the following manner: an equivalent quantity of ground or granulated sulphate of iron, or chloride of sodium, is mixed with the other of these salts in solution, absorbed into sawdust or other suitable matter; and then an equivalent of hydrate of lime is stirred in. This modified material, after being used in dry purifiers for purifying coal gas, affords by lixiviation a mixed solution of sulphate of soda and muriate of ammonia; sulphur and cyanogen also may be extracted from it, as in the former case. Sometimes the sulphate of iron is replaced by sulphate of copper; and then the resulting oxide, of course, is the oxide of that metal instead of the oxide of iron.

The patentees claim, under this head, the combination of processes above described for making a purifying material, containing chloride of calcium, and precipitated oxide of iron or copper; and likewise the composition of the modified material, as described. They also claim the use of both kinds of materials for purifying coal gas.

Another part of the invention consists in purifying coal gas by means of a cheap material, made by mixing refuse sulphate of lime or gypsum, in a finely divided state, with sulphate of iron. The sulphate of iron should be either ground fine or granulated, and mixed with sawdust, or other matter, suitable for separating its particles; or it may be merely mixed, in a divided state, with the earthy salt, or absorbed into its mass, or into sawdust, or other porous matter. The gypsum should be previously baked at a red heat, to prevent its tendency to solidify with water. The material, thus prepared, is used in dry purifiers, in the way well understood for purifying by hydrate of lime. For the sulphate of iron other metallic salts may be substituted with similar results; such, for example, as muriate of iron, sulphate or muriate of zinc, sulphate or muriate of manganese, or even sulphate or muriate of copper; but sulphate of iron is preferred. The resulting mass is either used as a manure, or else it is subjected to certain known chemical processes for obtaining from it an ammoniacal salt, or salts, sulphur, and cyanogen.

The claim under this head is for the purification of coal gas by the use of sulphate of lime, mixed with any of the metallic salts above named; and the use of the spent purifying material as a manure.

Another improvement consists in causing impure coal gas to pass through dry purifiers charged with a porous solid material, which is made by mixing, in about equivalent proportions, hydrated or precipitated oxide of iron, with carbonate of lime, magnesia, carbonate of magnesia, or magnesian limestone, in fine powder, or else burned or slaked, either by themselves, or rendered more pervious to the gas by sawdust, or other suitable matter. A mixture of precipitated oxide of iron and lime answers the same purpose, and was claimed by Mr. Laming, under a former patent. In each of the above cases oxide of copper may be substituted for the oxide of iron. All the several compounds, when they begin to act on the impure gas, purify it from sulphuretted hydrogen and cyanogen; and any one of them, having been once made foul, and afterwards placed in contact with atmospheric air for a few hours, acquires the property of purifying coal gas from ammonia also. The spent materials afford, by processes well known, cyanogen, sulphur, and ammoniacal products.

The patentees claim, under this head, the purification of coal gas, by mixtures made as described, whether with hydrated or precipitated oxide of copper or of iron.

Another part of the invention consists in a particular way of using chloride of magnesium, or sulphate of magnesia, for withdrawing from coal gas ammonia and carbonic acid. Sawdust or other solid matter calculated to expose an extensive surface to the gas, without opposing great resistance to its passage, is caused to absorb a saturated solution of one or both of the above named salts; or those salts may be mixed, singly or together, in a divided and solid state, with sawdust or other suitable matter, in a damp state; and then the mixture is placed in dry purifiers, through which the gas is made to pass in its way from the condensers to the gas-holders. When the gas ceases to be purified from its ammonia, the contents of the purifier are taken out and washed, to obtain an ammoniacal solution; and a new charge of similar purifying materials is introduced into the purifier.

The claim made under this head is for the extraction of ammonia and carbonic acid from coal gas, by chloride of magnesium, or sulphate of magnesia and water, diffused through sawdust or other solid matter, capable of exposing an extensive surface of the re-agents to the gas, without materially impeding its passage.

A further improvement consists in purifying coal gas by the use of a solid material, containing chloride of magnesium or of calcium, or sulphate of magnesia, mixed with hydrated or precipitated oxide of copper. To make this purifying material, the patentees take sawdust, or other suitable matter, wetted with a strong solution of suitable matter, wetted with a strong solution of muriate or sulphate of copper, or else either of those salts of copper in a finely-divided state, and mixed with moistened sawdust or other suitable matter, and they mix therewith enough lime, magnesia, or its carbonate, or magnesian limestone, burned and slaked with water or powdered, to decompose the salt of copper into precipitated oxide of the metal, and a salt of lime or magnesia, or both. Or, instead of making extemporaneously both or either of the salts of magnesia and lime and oxide of copper, they mix sulphate of magnesia or chloride of magnesium or of calcium, ready formed and in a state of mechanical division, or in solution, with oxide of copper and sawdust, or other suitable matter. These purifying materials are used in dry purifiers, like hydrate of lime. They can be employed for removing ammonia, carbonic acid, and sulphuretted hydrogen from the gas; or they may be used for the latter impurity without the two former. In the first case, it is found useful to add to them about half an equivalent of fine carbonate of lime, or of carbonate of magnesia, or of both; and in the latter case it is preferred to make either the same addition, or, in lieu thereof, to add about the same quantity of caustic lime or magnesia, or of both of them. When the used material will no longer purify the gas from sulphuretted hydrogen, either it is taken out of the purifier and exposed to the atmosphere, or else a current is directed through it while in that vessel; a vent-hole in the purifier, below the level of the foul purifying matter being open, or not, at the same time, as may be found necessary. The purifying energy of the material is thus restored, and this alternate expenditure and restoration of energy can be repeated a number of times, until the material becomes sufficiently charged with sulphur and with ammoniacal and cyanogen products, or either of them, to render it worth while to extract it or them in any known way.

The patentees claim under this head, the purifying coal gas by the repeated use of a solid material, containing sulphate of magnesia, or chloride of magnesium, or calcium, or more than one of those re-agents, in combination with oxide of copper, and mixed or not with lime or magnesia, or both, or either, or both of the carbonates of those earths.

The next part of the invention consists in a process for converting the ammoniacal liquor, produced in making gas, or by distilling animal matters, into sulphate of ammonia. By repeatedly using the same portion of hydrated or precipitated oxide of iron or copper, in conjunction with lime, magnesia, carbonate of lime, carbonate of magnesia, or any compound of lime or magnesia, susceptible, under the circumstances in which it is used, of being decomposed by carbonate of ammonia,—for purifying coal gas, with subsequent exposure to atmospheric air, the spent material eventually becomes in great part changed into sulphate of lime or sulphate of magnesia, mixed with oxide of a metal. When this has taken place, the spent material is mixed in a vat for an hour or two, with nearly as much of the ammoniacal liquor as it will decompose; the fluid is next drawn off and filtered; the saturation of any ammonia which it may contain in a volatile state is effected by sulphuric acid; and then it is evaporated to obtain crystals of ammoniacal sulphate. The same process is followed by another good result; for the decomposition of the carbonate of ammonia by the sulphate of lime, or sulphate of magnesia, reproduces in the spent material a carbonate of the earth, which fits it for beginning anew the work of purifying coal gas.

The patentees claim the use of the spent materials, above described, for converting solutions of carbonate of ammonia, mixed or not with hydrosulphate of ammonia, into solutions of ammoniacal sulphate; by which use, also, the sulphate of lime or sulphate of magnesia, in the said mixtures, is changed into carbonate of lime, or carbonate of magnesia.

When solid or porous mixtures, containing hydrated or precipitated oxide of iron or copper, or a salt of either of those metals, decomposable into hydro-sulphuret of the metal, are employed to absorb sulphuretted hydrogen from coal gas, and are afterwards brought into contact with atmospheric air, the mixture rapidly absorbs oxygen, and thereby acquires an elevated temperature, greater in proportion as it is free from moisture. In certain cases, when the materials are at first, or become by use, dry to the touch, their temperature during the subsequent absorption of oxygen rises much higher than is desirable. One way of preventing this injurious accession of heat is by communicating humidity to the mixture of materials, at a proper time; and this constitutes another part of the invention. This improvement is put into practice, either by sprinkling the used purifying materials with water, on removing the cover from the vessel, which contains them; or by pipes, properly disposed within the vessel, distributing water over the surface of the materials, without the cover being removed; or by sprinkling the materials with water, after they have been thrown out of the vessel; or lastly, by placing the purifier in communication with a steam-boiler, and directing through the used materials a sufficient quantity of the vapour of water to moisten them and subsequently submitting them to the influence of a current of atmospheric air, also directed through them. The patentees state, that they know it to be necessary that the metallic oxides used for purifying coal gas from sulphuretted hydrogen should be hydrated; that is to say, combined with a certain portion of water in a dry state; but experience has proved to them, contrary to common opinion, that the said oxides act less energetically on the sulphuretted hydrogen in the gas, and also that they regain their expended energy less suddenly, when they contain water in a liquid state, than when they are free from hygrometric water.

The patentees do not claim the regeneration of the purifying energy of any spent purifying mixtures, by exposing them to atmospheric air; but what they claim is, the means, above described, for checking the rapidity of the regenerating action, and, consequently, preventing the temperature of the materials from rising to a pernicious height;—viz., by wetting them with water, or by condensing steam in their mass, either in or out of the purifier, at any time after they commence to purify the gas, and before they are put in communication with the atmosphere.

The patentees have found that mixtures containing hydrated or precipitated oxide of iron, changed into hydro-sulphuret of iron, by purifying coal gas from sulphuretted hydrogen, do not readily re-absorb oxygen, and, consequently, do not readily recover their purifying energy at temperatures below 32° Fahr.

Now, another improvement consists in applying to such used mixtures, during frosty weather, atmospheric air, artificially warmed to about 60° Fahr.: by the ordinary operations of the "retort house," or in any other convenient manner. The warmed air may be used there, or conducted thence to the purifiers, by suitable pipes, in which a draft is established by any known means.

The claim under this head is for the use of air, artificially warmed, for promoting, in cold weather, the regeneration of hydrated oxide of iron, in mixtures which have been used for purifying coal gas from sulphuretted hydrogen,—whether the warmed air be conveyed to the used purifying mixtures, or the latter be carried to the warm air.

Another part of the invention consists in the use of phosphate of lime, dissolved in hydrochloric acid, for purifying coal gas, and for decomposing the ammoniacal liquors produced in making gas, and in the distillation of animal matters, and the application of the products as manures. In carrying out the improvement, bones, or other form of phosphate of lime, are dissolved in hydrochloric acid. This solution is prepared for purifying gas by mixing it with sawdust or other suitable solid matter; and thus it is exposed to the impure gas in dry purifiers. To use the solution for decomposing ammoniacal liquors, one of the fluids is added to the other, until the hydro-sulphuric and carbonic acids combined with the ammonia have escaped. To facilitate the transport of the product, and its application as a manure, it is heated in pans until it becomes dry. The product of the purification of gas is also a good manure, mixed as it is with the sawdust or other absorbent matter used.

The patentees claim under this head the use of a solution of phosphate of lime in hydrochloric acid, for purifying coal gas and for saturating ammoniacal solutions; and also the use of the products as manure.

Another part of the invention relates to certain processes for obtaining, in an economical manner, one of the re-agents which the patentees use for purifying gas,—namely chloride of calcium. In certain chemical works, hydrochloric acid gas is a residuary product,—not only of no value, but even costly to get rid of without nuisance to the neighbourhood. One of the processes consists in causing hydrochloric acid gas to pass, in a heated state, over beds of lime, or carbonate of lime, in its way from the furnaces, where it is generated, to the condensers, where it would else become absorbed into water. The beds of lime, or carbonate of lime, are formed on the bottom of the ordinary conduits; two conduits being arranged in a line, and worked and discharged alternately. When the lime in one passage has been converted into chloride, the draft through it is diverted into the neighbouring passage by means of dampers arranged for that purpose; and the finished charge is withdrawn through doors made at convenient distances. When this is done, the bed is re-charged with lime or its carbonate, in readiness to receive the current of hydrochloric acid, after it shall have saturated the lime in the second conduit. When this saturation is completed, the dampers are reversed, so as to divert the acid gas again into the first conduit, while the charge of the second is being withdrawn, preparatory to re-charging it a second time; and so on continually. By the second process, hydrochloric acid is obtained in a concentrated state, preparatory to its saturation in a fluid form by lime or its carbonate, or to its application to other uses. This process is carried on with only one conduit leading from the furnaces where the hydrochloric acid is generated. The conduit is lined with hard glazed bricks, or tiles, or sandstone; and its bottom is so constructed, that any fluid formed within it shall escape by a pipe adjusted to its lowest part. Along this conduit a number of porous earthenware vessels are arranged in a line or lines, standing on its floor, and built into its arch or cover up to their necks. These vessels are filled with water, and made to communicate, by means of syphons, with one another, and with a reservoir of water placed with its highest part on the same level as the mouths of the earthenware vessels. By well-known arrangements, the water is kept at a constant level in the reservoir, and consequently at a constant level in the earthenware vessels which communicate with it. The consequences of this arrangement are, that the water contained in the vessels within the heated conduit is speedily raised to a temperature of 212° F.; that the gaseous contents of the conduit are reduced to that temperature, or nearly so,—and that the water which exudes from the porous earthenware absorbs as much hydrochloric acid gas as it can combine with. Now, as strong hydrochloric acid is condensable at a temperature above 212° Fahr.; and as the vapour of water is not condensable at that temperature, the strong acid flows down the outsides of the porous vessels and runs in a stream to the most depending part of the passage, where it escapes by the pipe placed for that purpose. By treating the acid so obtained with lime or its carbonate, chloride of calcium or muriate of lime is obtained, with hardly any cost for evaporation.

The patentees claim, under this head, making chloride of calcium, by causing the hydrochloric acid gas, which results from the decomposition of common salt by sulphuric acid, to act on lime or carbonate of lime in its passage from the furnace where the decomposition is effected; and also the collecting of concentrated hydrochloric acid, for making chloride of calcium or other purposes, by condensing hydrochloric acid gas in water by means of earthen vessels built into a conduit or flue, conducting from furnaces in which chloride of sodium is decomposed by sulphuric acid, and containing water kept at about 212° Fahr. by the heated products of the said furnaces.

The next part of the invention is a new way of using certain forms of carbon for purifying coal gas and obtaining ammonia therefrom. It consists in alternately causing the material to absorb impurities from the gas, and to discharge them under the influence either of heat or of a current of air, or steam directed through the purifying material. In carrying out this improvement, a dry lime purifier, or other convenient vessel, is filled with animal charcoal in coarse powder, and impure coal gas is directed through it, until it no longer issues from the vessel pure. The gas is then sent in another direction, and a current of steam or air, heated or otherwise, is passed through the foul material; the volatile products being received into any desirable acid or other substance calculated to fix the ammonia, or else the ammonia, combined with carbonic and hydro-sulphuric acids, is condensed by water, or by the abstracting of heat, in any suitable apparatus. If steam be used, it brings away nearly the whole of the ammonia, but it damps the purifying material, which then needs to be dried by a current of hot air or otherwise; and if air be used, in the first instance, to bring away the ammonia, part of it becomes sulphate of that base, and must be removed by washing. In addition to, or without the introduction of air or steam among the purifying material, it may be heated by steam or hot water contained in a jacket around the vessel, or in pipes within it; or the foul material may be removed from the purifier and heated to about 212° Fahr. in any suitable close vessel. Coke, wood, charcoal, or peat charcoal may be substituted for animal charcoal, in the process above described, but with inferior results.

The patentees do not claim the exclusive use of any form of carbon for absorbing the impurities of coal gas; their claim being for the means above described, for making coke and charcoal repeatedly useful for purifying coal gas, and for obtaining its ammonia by their agency.

Another part of the invention consists of certain processes by which prussiate of potash, prussiate of soda, and prussiate of ammonia, are obtained from prussiate of lime. With respect to prussiate of potash, the process is to mix well together equivalent quantities of prussiate of lime and sulphate of potash, or carbonate of potash, previously dissolved in separate portions of water; and then, after subsidence of the sulphate or carbonate of lime which is formed, to evaporate and crystallize the clear solution. The prussiates of soda and of ammonia are made in like manner, by substituting the sulphates or carbonates of the respective bases for the sulphate or carbonate of potash.

The claim under this head is for the manufacture of the prussiates of potash, soda, and ammonia, by decomposing solutions of the sulphates or carbonates of those bases by solutions of prussiate of lime.

Another improvement consists in a process for obtaining carbonic acid gas for converting the hydrosulphate of ammonia in gas liquor into carbonate of ammonia, and for other useful purposes to which carbonic acid gas is applicable. It is known that hydrosulphate of ammonia is decomposable by carbonic acid, and that hydrosulphate of ammonia exists in gas liquor. To change it into carbonate of ammonia, the patentees proceed as follows:— They make a mixture of deutoxide of copper and charcoal, or other form of carbon, in fine powder, in the proportion of twelve parts, by weight, of the former to one part of the latter, and introduce the mixture into a retort, made red hot, and furnished with an eduction pipe which passes through cold water and finally enters into gas liquor. The formation of carbonic acid gas soon takes place, by the union of the carbon with the oxygen of the metal: and this gas, combining with the base of the hydrosulphate of ammonia, combined in the gas liquor, converts it into carbonate, causing hydrosulphuric acid to escape. When the carbonic acid ceases to come away, nearly all the carbon will have disappeared from the retort, and the copper which it contains become reduced to the metallic state. The charge is then drawn and left to cool, while a second charge, of similar materials, is being worked off; during which time the copper re-absorbs oxygen from the air, and becomes again deutoxide of copper, which may then be used anew with fresh carbon.

The patentees claim making carbonic acid gas for converting hydrosulphate of ammonia into carbonate of ammonia, and for all other purposes in the arts, by exposing a proper mixture of deutoxide of copper and carbon in powder to a red heat in suitable vessels.

The last part of this invention is a process for consilidating peat to be used in furnishing gas or charcoal, or for feul. The process is as follows:—The peat, without being previously dried, is treated with water in a mill in a way similar to that in which chalk is treated for the manufacture of whitening, and which is well understood. The resulting liquor is made to pass through a strainer of wire-work (fine enough to prevent the passage of the large fibres) into tanks or backs, cut in the earth, or built upon the surface of the ground if necessary; where it is left to deposit the finer parts of the peat. When this is effected, the supernatent liquor is run off from the deposit, and the magma taken out from the tanks or backs and dried, either by the air, by the sun, or on arches of brick or other absorbent material, heated by flues underneath.

The patentees claim under this head the separation of the grosser from the finer parts of the peat, and the consolidation of the latter by the process above described.

Gas-light, Purification of. The purification of coal gas has lately received one of those important improvements, which constitute an era in the practical application of science to the arts. From the commencement of the manufacture of gas up to a very recent period, the only agent in use for the removal of the impurities of coal-gas was the hydrate of lime. The impurities in question are, as is well known, carbonic acid and sulphuretted hydrogen united to ammonia, and held in the gas more by a principle of diffusion than from their own proper volatility. Hence mere condensation by cold, or the application of water, unless both of these are employed to an injurious excess, will not combine with or precipitate the bicarbonate and hydrosulphate of ammonia present in impure coal gas. The hydrate of lime, however, readily decomposes both of these salts, with the production of carbonate and hydrosulphate of lime and the liberation of free ammonia, the greater part of which may subsequently be removed by the use of a dilute acid, or the application of cold water in an apparatus similar to the "cascade chemique" of Clement Desormes. Thus, then, it was possible by lime to remove the whole, or at least nearly the whole, of the impurities of coal-gas, and as we have before stated, this, up to within a very recent date, was the general practice whenever coal-gas was manufactured. But the use of lime in this way entailed many and serious disadvantages in a sanitary point of view, to obviate or rather to diminish which considerable outlay was incurred in large towns, for it is a property of the hydrosulphate of lime to be decomposed with singular rapidity by carbonic acid, and as the atmosphere, more especially in crowded localities, always contains a notable proportion of this latter gas, it follows that the hydrosulphate of lime begins to decompose the moment it comes in contact with the air, and, consequently, an intolerable nuisance and pestilential effluvium were thus originated, not only in the neighbourhood of the gas-works themselves, but also in those localities to which this gas-lime refuse happened to be transported; of which a lamentable illustration occurred not long ago in Pimlico, where a sewer had been covered over by this kind of refuse; and though three or four years had intervened between the deposition of this matter and the accident we now relate, yet no less than five healthy individuals were struck dead, as if by lightning, on entering the sewer beneath the spot where the refuse lime had been placed. With so terrific a proof of the deleterious action of the hydrosulphate of lime, even after many years had elapsed, it becomes superfluous to dwell upon the necessity which existed for discontinuing the formation of this poisonous substance, and, fortunately, science has stepped in at the eleventh hour to the relief of the public.

About the year 1847, a Mr. Laming, of Paris, took out a patent for the employment of various metallic oxides in lieu of lime for the purification of gas, which oxides were used at the same time or in combination with muriate of lime. The effect of this arrangement was two-fold, for as we have seen that the impurities to be taken away consist of ammonia, carbonic acid, and sulphuretted hydrogen, then by the use of muriate of lime, Mr. Laming was able to remove the carbonic acid and ammonia, whilst by the metallic oxide he removed the sulphuretted hydrogen; producing in the first case muriate of ammonia and carbonate of lime, and in the second a metallic sulphuret and water. The oxides patented were those of manganese, iron, zinc, and lead; but there was this insuperable difficulty connected with their employment, that as they could be formed only by the decomposition of a metallic salt and its equivalent

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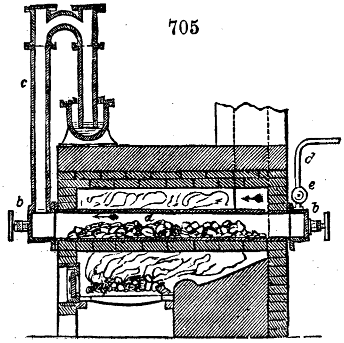
of lime, they necessarily cost, for an equal amount of work done, the whole value of the lime plus that of the metallic salt. The expense of purification by this plan, therefore, stood as an insurmountable barrier to its introduction, though the peculiar defect of lime was entirely got rid of in the use of the metallic oxide, as this did not suffer decomposition by atmospheric carbonic acid, and therefore evolved no sulphuretted hydrogen. Nevertheless, the process languished, and threatened to die out on the score of cost. Mr. Laming's first essays with this patent seem to have been made almost entirely with the oxides of manganese and lead, and oxide of iron does not appear to have been employed or tried on a large scale until about three years ago, when, in conjunction with Mr. F. J. Evans, of the Chartered Gas Works, it was put in use by Mr. Laming at Westminster. The success of the experiment was complete as to purification, but the question of expense could only be decided by a few consecutive trials, and therefore, fresh materials were sent for this purpose, whilst the old, or as it was called "spent" material was cast on one side. During the progress of the ensuing experiments it was, however, observed by Mr. Evans, that this spent material, consisting as it did of black sulphuret of iron, rapidly regained its original red colour, and looked like oxide of iron. This induced him to give it another trial in the purifier, when, to his astonishment, he discovered that its purifying power was completely restored, and that, in fact, it might be used over and over again, 10, 15, or 20 times, or even more in succession, nothing being required to restore its power but a few hours' exposure to the air. From that moment the practical employment of oxide of iron in the purification of coal-gas became *un fait accompli;* for the question of expense was altogether done away with by a material which, though costly in the first instance, soon ceased to be so from repeated and continuous usage without additional outlay. And it is here worthy of remark, that oxide of iron is the only oxide yet discovered which fully answers this purpose, for the sulphurets of manganese, zinc, and lead, do not become reconverted into oxides by simple exposure at ordinary temperatures to the action of the air. And as oxide of iron is contained in the blood of all animals, it opens out an interesting question in physiology, how far this gas purification process may be analogous to that of the blood, through the agency of the pulmonary system. We shall now, however, merely give a condensed view of the oxide of iron method, as practised at the Westminster and other gas works, without offering more than a few brief theoretical remarks by way of explanation.

Impure coal-gas, as it leaves the condenser, contains about two per cent. in bulk of carbonic acid, and one per cent. of sulphuretted hydrogen, with a quantity of ammonia, generally insufficient to saturate these two acids, though this varies much with the variations of the weather and the state of the condenser. For the most part, however, the amount of ammonia is equal to the carbonic acid, and in this case the new process is perfect; but if the ammonia be less than will saturate the carbonic acid, then the excess of this acid remains in the gas, and to this extent the coal-gas may be said to be impure. Taking the normal condition of gas as it quits the condenser, it is first made to traverse a quantity of sawdust, saturated with a very strong solution of muriate of lime. Here double decomposition goes on, accompanied by the formation of carbonate of lime and muriate of ammonia, and the gas becomes deprived of its carbonic acid and ammonia, consequently it now contains only sulphuretted hydrogen; and when the muriate of lime in the sawdust is totally decomposed, the muriate of ammonia which it then contains is dissolved out by lixiviation, and crystallised as a marketable product. The impure gas is next transmitted through a mixture of the hydrated peroxide of iron and sawdust, damped with a solution of muriate of lime, by which the whole of the sulphuretted hydrogen is absorbed, and also any traces of carbonate of ammonia which may have escaped the first purifier. In this way the peroxide of iron is reduced to the state of protoxide, with the formation of water and deposition of half an atom of sulphur, whilst the protoxide of iron as it is produced reacts upon the remaining sulphuretted hydrogen, and yields a hydrated proto-sulphuret of iron of a black colour, so that the resulting products are water, sulphur, and hydrated protosulphate of iron. So soon, however, as these are exposed to the air, the iron of the protosulphuret combines with oxygen and liberates free sulphur, whilst it nevertheless retains the water of combination belonging to the protosulphuret, thus generating a mixture of hydrated and anhydrous peroxide of iron; and as it is the former of these alone which is useful in purification, there is after each renewal a slight loss of power, and this slowly increasing ultimately renders the whole mass inefficacious after from 18 to 20 exposures. At the same time the free sulphur in the material goes on augmenting, and at last a period arrives in which the mixture becomes pyrophoric, and it is almost impossible to prevent it from catching fire. The effect of the muriate of lime is to diminish this tendency; but this gives rise to the presence of carbonate of lime, as we have seen above, and when much carbonate of lime has made its appearance, then the disposition of the sulphur to form sulphuric acid is increased by the readiness for its absorption by the carbonate of lime, and therefore the proneness to inflammation is again manifested; so that in practice a small specimen of this material is seldom used more than twenty times in succession before it is removed from the gas works. It is, however, now very far from being valueless, as it not only contains a vast amount of free sulphur, but also of ferrocyanic acid; a product scarcely to have been expected in a commercial sense. Nevertheless, it is found that one ton of Newcastle coals gives off in distillation sufficient cyanogen to produce from 5 to 8 lbs. of Prussian blue with the hydrated oxide of iron; and it is part of the process now carried on by Mr. Laming at Mill Wall, to extract this ferrocyanic acid from the spent material, and convert it into prussiate of potash or Prussian blue at pleasure. The great advantage of this invention is not therefore confined to its sanitary details, but extends into the merit of having discovered a new and fertile source for the production of an article of great commercial value, and rendered both useful and profitable that which was previously a pestilential waste threatening to interfere very seriously with the progress of gas manufacturing.—*Mr. L. Thompson.*

Lowe and Evans's Improvements. On the 20th January, 1852, a patent was granted to George Lowe, of Finsbury-circus, in the city of London, civil engineer, and Frederick John Evans, of Horseferry Road, in the city of Westminster, civil engineer, for improvements in the manufacture of gas for the purpose of illumination, and of improvements in the purification of gas.

The first part of this invention refers to certain means of enriching or improving the quality of gases, so as to render them fit for the purposes of illumination.

In carrying out this improved manufacture of gas, the patentees pass gas, obtained from any of the sources hereinafter specified, through heated retorts containing cannel coal, coal, lignite, resin, pitch, tar, oil, retinite, or other substance or substances capable of yielding carburetted hydrogen gas: by which means such a combination of rich and poor gases may be produced as will be exactly suited to the purposes of illumination. For this purpose, it is proposed to use retorts open at both ends, as shown in the drawing given in *fig.* 705., which represents a longitudinal vertical section of the apparatus employed in carrying out this part of the invention. Only one retort is exhibited; but a similar arrangement of retorts may be adopted to that in general use in gas-works. *a* is the retort, set in a suitable furnace for heating the same; and *b*, *b* are mouth-pieces and lids, fitted to both ends of the retorts. *c* is the pipe for carrying off the gaseous products generated in the retort; and *d*, is a pipe for introducing into the retort the gas which is intended to combine with the gaseous products of the substances under distillation in the retort. As soon as the retort is charged with coal or other carbonaceous matter, a cock *e*, in the pipe *d*, is opened, which allows the gas to flow into the retort; and it then passes in the direction of the arrows, and mingles with the gas that is evolved from the carbonaceous matters contained in the retort: whereby a compound gas is formed, possessing a much higher illuminating power than could have been obtained had the combination taken place after instead of at the time of the generation of the gas in the retort *a*. The gas, which is brought to the retort by means of the pipe *d*, may be forced into the retort, so as to overcome the internal pressure put on the retort by means of the hydraulic main; or, instead thereof, an exhauster may be applied to draw off the gas from the retort. Should tar, oil, resin (previously melted), or any liquid hydrocarbon be employed for the generation of the gas, it is to be run into the retort in the way generally adopted for making oil or resin gas.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The sources from which the patentees propose to obtain inflammable gases, to be applied as above indicated, are wood, sawdust in a damp or dry state, spent tanner's bark, and other like substances capable of yielding an inflammable gas. These substances must be put into a red-hot retort, and distilled like coal. The resulting gases may be either purified at once, or passed directly to the retort containing the coal or other carbonaceous materials. As a general rule, however, these gases are preferred to be stored in gas-holders for use; as, in that case, a more uniform and constant supply to the coal retort may be relied on.

Another source of inflammable gas is from coal of an inferior description, or from peat. These substances having been distilled in a retort, the resulting gas can be then employed as above indicated. It is also proposed to conduct carbonic oxide gas into retorts containing carbonaceous matters under distillation. This gas the patentees obtain from carbonic acid, by passing the latter gas (which may be obtained from any convenient source) through a retort or furnace containing red or white hot coke. Or, they utilize a portion of the gases generated in furnaces, by collecting these gases and converting the carbonic acid they contain into carbonic oxide, by passing them through a retort or furnace, as described for treating carbonic acid; or the gases may be conducted directly into retorts, wherein carburetted hydrogen is being generated, for the purpose of effecting the desired combination.

From the foregoing description, it will be understood, that the object of this part of the invention is to obtain gas of a uniform quality,—that is, possessing a definite amount of illuminating power. Now, it is well known that if the gas be too rich in carbon it will burn with a dull flame, and give off a large amount of smoke; and that, if deficient in carbon, it will burn with a blue flame, and possess very little illuminating power. It is therefore proposed to mix the rich and poor gases, obtained as above described, in such proportions as will be needful to produce a highly illuminating quality of gas. As the proportions will depend entirely on the quality of the gases to be combined, no rule can be laid down for the amount of the gas required to be passed into the retorts, wherein the distillation is proceeding. The mode, however, in which the gas burns, on issuing from the retort, will be a sufficient test for the workmen in attendance.

The second part of this invention refers to the purification of coal-gas from sulphuretted hydrogen; and consists in effecting this operation by the use of what has been considered by chemists to be the ferrate of potash, but what is now found to be a peroxide of iron in a peculiar state, and such as results from the employment of the following means:—First the patentees heat together peroxide of iron and caustic potash or soda to a dull red heat, by which a kind of ferrate or ferrite of potash or soda is produced; and when this substance is washed in water, it undergoes decomposition, with the reproduction of caustic potash or soda (which remains in solution), and the precipitation of peroxide of iron in the state fit for the purification of gas. All or any of the peroxides of iron may be used for the above purposes, and will, by its means, become useful for purifying gas, though previously inert; and the solution of potash or soda, when evaporated to dryness, may be again and again employed upon fresh portions of peroxide of iron, so as to communicate to them the peculiar property desired. Or peroxide of iron may be heated with a smaller quantity of caustic potash or soda, and a portion of common salt, in order to economize the potash or soda: the heat in this case should be, as before, a dull red; and the same measures must be adopted for recovering the potash or soda and common salt, which may be used over and over again with fresh portions of peroxide of iron. Or the patentees heat the common hydrated peroxide of iron, to about 600° Fahr.,—taking care that the heat never reaches a bright red; and in this way they obtain a peroxide of iron, having the requisite properties. Or they heat in the same way, and with the same precautions, such of the native ochres or ferruginous compounds as will, after such treatment, become rapidly black upon being subjected to the action of a stream of sulphuretted hydrogen.

A quantity of peroxide of iron, fit for purifying gas, having been procured, by any of the means thus indicated, the oxide is next to be mixed with sawdust or other convenient material, and damped slightly with water; and the mixture is then to be spread in a dry lime purifier, and used in the way adopted with hydrate of lime; or it may be mixed with water, and run into a wet lime purifier, and used in the way adopted with regard to lime when employed in this kind of apparatus. In both cases it will be necessary, after the peroxide of iron has ceased to act upon the gas, to expose it to the air, by which its energies are renewed, so that it may be again and again used for the purification of gas. With the dry lime purifier, simple exposure is all that is required. With the wet lime purifier, the mixture must be run out and left at rest for some time; then, when the fluid has entirely separated from the solid part, it may be allowed to escape; and as the solid portion dries, its power will become renewed: after which it may be mixed with water and employed as before. The renewal of the peroxide of iron, in both these cases, is known by its changing from black to red or deep brown.

Another part of the invention relates to the use of the sulphite and bisulphite of lead for the removal of the sulphuretted hydrogen from coal-gas.

These substances are to be employed singly or together, mixed with water, in a wet lime purifier, exactly as is practised with regard to lime. When they cease to purify the gas, the mixture is run out of the purifier; and after the water has been removed by subsidence and decantation, or by a filter, the residue is dried and burned, so as to make sulphurous acid, which is employed in the manufacture of fresh sulphite or bisulphite of lead, or in the production of sulphuric acid. The matter which remains, after this burning process, is carefully roasted, and thus converted into oxide of lead or litharge, from which sulphite or bisulphite of lead may be again produced.

The patentees claim the combining of gases which possess different degrees of illuminating power, by the introduction of gas, obtained in any of the ways above indicated into retorts or vessels containing carbonaceous matters under distillation. They also

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claim, as their improvements in the purification of gas, First,—the use of anhydrous peroxide of iron prepared as above described; and, Secondly,—the use of sulphite and bisulphite of lead, for the removal of sulphuretted hydrogen from coal-gas.—*Newton's Journal.*

We are indebted to Mr. Thomas G. Barlow, an eminent engineer, for a vast body of information on coal-gas, contained in his excellent *Journal of Gas Lighting*, commenced on the 10th of February, 1849, and continued in monthly numbers ever since. His first number presented a list of the London Gas Companies, and the value of their shares at the Stock Exchange, to which we have added the ruling rates in the present year.

Paid up.	Name.	January, 1848.	January, 1849.	September, 1852.
£		£ £	£ £	£ £
25	Commercial	25 to 26	25 to 26	30 to 32
150	City of London	285 — 290	240 — 245	124 — 126
50	Chartered	58 — 59	48 — 49	36 — 37
50	Equitable	38 — 39	33 — 35	25 — 26
50	Imperial	80 — 84	62 — 64	75 — 80
50	Independent	- - -	60 — 62	46 — 47
50	London (Vauxhall)	- - -	10 — 20	2½ — 3
50	Ditto (preference)	- - -	20 — 30	15 — 18
49	Phœnix	35½ to 36½	28 — 30	26 — 27
90	Ratcliff	78 — 80	72 — 74	60 — 65
25	South Metropolitan	28 — 30	21 — 23	20 — 22

GENERAL SUMMARY.

For lighting London and its suburbs with gas, there are—
18 public gas works.
12 do. companies.
2,800,000*l.* capital employed in works, pipes, tanks, gas-holders, apparatus.
450,000*l.* yearly revenue derived.
134,300 private burners supplied to about 40,000 consumers.
30,400 public or street do. N. B. about 2650 of these are in the *city* of London.
380 lamplighters employed.
176 gas-holders; several of them double ones, capable of storing 5,500,000 cubic feet.
890 tons of coal used in the retorts on the shortest day, in 24 hours.
7,120,000 cubic feet of gas used in the longest night, 24th December.

About 2500 persons are employed in the metropolis alone, in this branch of manufacture.

Between 1822 and 1827 the quantity nearly doubled itself, and that in 5 years.

Between 1827 and 1837 it doubled itself again.

The consumption of coals of all kinds for the supply of gas to the metropolis during the year ending June, 1852, is almost exactly 408,000 tons, which on an average would yield about 4,000 millions of cubic feet of gas.

GAS-HOLDER; a vessel for containing and preserving gas, of which various forms are described by chemical writers.

GASOMETER, means properly a measurer of gas, though it is employed often to denote a recipient of gas of any kind. See the article GAS-LIGHT.

GAUZE WIRE CLOTH, is a textile fabric, either plane or tweeled, made of brass, iron, or copper wire, of very various degrees of fineness and openness of textures. Its chief uses are for sieves and safety lamps.

GAY-LUSSITE, is a white mineral of a vitreous fracture, which crystallizes in oblique rhomboidal prisms; specific gravity from 1·93 to 1·95; scratches gypsum, but is scratched by calcspar; affords water by calcination; it consists of carbonic acid 28·66; soda, 20·44; lime, 17·70; water, 32·20; clay, 1·00. It is in fact, by my analysis, a hydrated soda-carbonate of lime in atomic proportions. This mineral occurs abundantly in insulated crystals, disseminated through the bed of clay which covers the *urao*, or native sesquicarbonate of soda, at Lagunilla in Columbia.

GELATINE; (Eng. and Fr.; *Gallert*, *Leim*, Germ.) is an animal product which is never found in the humours, but it may be obtained by boiling with water the soft and solid parts; as the muscles, the skin, the cartilages, bones, ligaments, tendons, and membranes. Isinglass consists almost entirely of gelatine. This substance is very soluble in boiling water; the solution forms a tremulous mass of jelly when it cools. Cold water has little action upon gelatine. Alcohol and tannin (tannic acid, see GALL-NUTS) precipitate gelatine from its solution; the former by abstracting the water, the latter by combining with the substance itself into an insoluble compound, of the nature of leather. No other acid, except the tannic, and no alkali, possesses the property of precipitating gelatine. But chlorine and certain salts render its solution more or less turbid; as the nitrate and bi-chloride of mercury, the proto-chloride of tin, and a few others. Sulphuric acid converts a solution of gelatine at a boiling heat into sugar. See Ligneous Fibre. Gelatine consists of carbon, 47·88; hydrogen, 7·91; oxygen, 27·21. See Glue and Isinglass.

This substance is produced by boiling the skin of animals in water, which in its crude but solid state is called *glue*, and when a tremulous semi-liquid, *size*. The latter preparation is greatly used by the paper-makers, and was much improved by the following process, for which Mr. William Rattray obtained a patent in May, 1838. The parings and scrows of skins are steeped in water till they begin to putrefy; they are then washed repeatedly in fresh water with the aid of stampers, afterwards subjected, in wooden or leaden vessels, to the action of water strongly impregnated with sulphurous acid for from 12 to 24 hours; they are now drained, washed with stampers in cold water, and next washed with water of the temperature of 120° F., which is poured upon them and run off very soon to complete their purification. The scrows are finally converted into size, by digestion in water of 120° for 24 hours; and the solution is made perfectly fine by being strained through several thicknesses of woollen cloth. They must be exhausted of their gelatinous substance, by repeated digestions in the warm water. The claim is for the sulphurous acid which, while it cleanses, acts as an antiseptic.—*Newton's Journal*, xiv. 173.

A fine gelatine for culinary uses, as a substitute for isinglass, is prepared by Mr. Nelson's patent, dated March, 1839. After washing the parings, &c., of skin, he scores their surfaces, and then digests them in a dilute caustic soda lye during ten days. They are next placed in an air-tight vat, lined with cement, kept at a temperature of 70° Fahr.; then washed in a revolving cylinder apparatus with plenty of cold water, and afterwards exposed to the fumes of burning sulphur (sulphurous acid) in a wooden chamber. They are now squeezed to expel the moisture, and finally converted into soluble gelatine, by water in earthen vessels, enclosed in steam cases. The fluid gelatine is purified by straining it at a temperature of 100° or 120° Fahr. I have examined this patent gelatine, and found it to be remarkably good, and capable of forming a fine calf's-foot jelly.

Very recently a very beautiful sparkling gelatine has been prepared under a patent granted to Messrs. J. and G. Cox, of Edinburgh. By their process the substance is rendered perfectly pure, while it possesses a gelatinizing force superior even to isinglass. It makes a splendid calves'-feet jelly and a milk-white blanc-mange. The patentees also prepare a semi-solid gelatine, resembling jujubes, which readily dissolves in warm water, as also in the mouth, and may be employed to make an extemporaneous jelly.

The gelatine of bones may be extracted best by the combined action of steam and a current of water trickling over their crushed fragments in a properly constructed apparatus. When the gelatine is to be used as an alimentary article, the bones ought to be quite fresh, well preserved in brine, or to be dried strongly by a stove. Bones are best crushed by passing them between grooved iron rolls. The cast-iron cylinders in which they are to be steamed, should be three times greater in length than in diameter. To obtain 1000 rations of gelatinous soup daily a charge of four cylinders is required; each being 3½ feet long, by 14 inches wide, capable of

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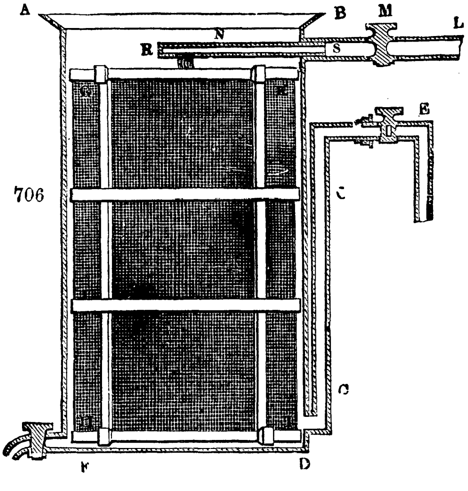

holding 70 lbs. of bones. These will yield each hour about 20 gallons of a strong jelly, and will require nearly 1 gallon of water in the form of steam, and 5 gallons of water to be passed through them in the liquid state. The 5 quarts of jelly produced hourly by each cylinder, proceeds from the 1 quart of steam-water and 4 quarts of percolating water.

The boiler should furnish steam of about 223° Fahr., at a pressure of about 4 lbs. on the square inch.

In *fig.* 706: A, B, C, D, represents a vertical section of the cylinder; G, H, I, K, a section of the basket or cage, as filled with the bruised bones, inclosed in the cylinder; E, C, C, the pipe which conducts the steam down to the bottom of the cylinder; L, S a pipe for introducing water into the interior; M, a stopcock for regulating the quantity of water (according to the force of the steam pressure within the apparatus), which should be 3½ quarts per hour; N is a tube of tin plate fitting tightly into the part S of the pipe L; it is shut at R, and perforated below with a hole; it is inserted in its place, after the cage full of bones has been introduced. *Fig.* 707. is an elevation of the apparatus. A, B, C, D, represent the four cylinders, raised about 20 inches above the floor, and fixed in their seats by screws; *h h*, are the lids; *g*, *g*, tubulures or valves in the lids; *i*, ring junction of the lid; *p*, a thermometer; *f*, *f*, stop-cocks for drawing off the jelly; *n*, *n* small gutters of tin-plate; *m*, the general gutter of discharge into the cistern *b*; *o*, a block and tackle for hoisting the cageful of bones in and out. *Fig.* 708. is an end view of the apparatus; *a*, the main steam-pipe; *a*, *b*, *c*, *c*, branches that conduct that steam to the bottom of the cylinder; *o*, the tackle for raising the cage; *s*, stopcock; *n*, small gutter; *m*, main conduit; *b*, cistern of reception.

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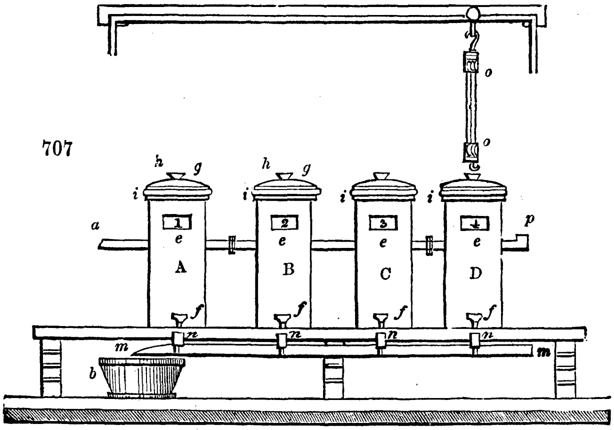

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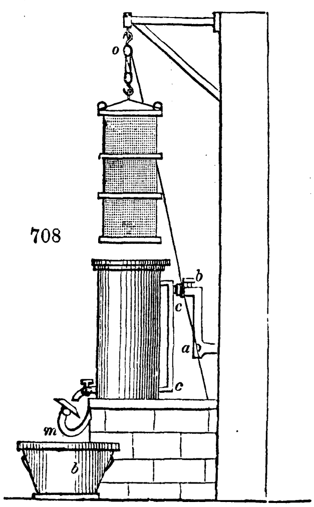

When a strong and pure jelly is wished for, the cylinder charged with the bones is to be wrapped in blanket stuff; and whenever the grease ceases to drop, the stopcock which admits the cold water is to be shut, as also that at the bottom of the cylinder, which is to be opened only at the end of every hour, and so little as to let the gelatinous solution run out, without allowing any of the steam to escape with it.

Butchers' meat contains on an average in 100 pounds, 24 of dry flesh, 56 of water, and 20 of bones. These 20 pounds can furnish 6 pounds of alimentary substance in a dry state; whence it appears that, by the above means, one fourth more nutritious matter can be obtained than is usually got. I am aware that a keen dispute has been carried on for some time in Paris, between the partisans and adversaries of gelatine as an article of food. It is probable that both parties have pushed their arguments too far. Calf's-foot jelly is still deemed a nutritious article by the medical men of this country, at least, though it is not to be trusted to alone, but should have a due admixture or interchange of fibrine, albumine, caseum, &c.

GEMS, are precious stones, which, by their colour, limpidity, lustre, brilliant polish, purity, and rarity, are sought after as objects of dress and decoration. They form the principal part of the crown jewels of kings, not only from their beauty, but because they are supposed to comprise the greatest value in the smallest bulk; for a diamond, no larger than a nut or an acorn, may be the representative sign of the territorial value of a whole country, the equivalent in commercial exchange of a hundred fortunes acquired by severe toils and privations.

Among these beautiful minerals mankind have agreed in forming a select class, to which the title of *gems* or *jewels* has been appropriated; while the term *precious stone* is more particularly given to substances which often occur under a more considerable volume than *fine stones* ever do.

Diamonds, sapphires, emeralds, rubies, topazes, hyacinths, and chrysoberyls, are reckoned the most valuable *gems.*

Crystalline quartz, pellucid, opalescent or of various hues, amethyst, lapis lazuli, malachite, jasper, agate, &c., are ranked in the much more numerous and inferior class of ornamental stones. These distinctions are not founded upon any strict philosophical principle, but are regulated by a conventional agreement, not very well defined; for it is impossible to subject these creatures of fashion and taste to the rigid subdivisions of science. We have only to consider the value currently attached to them, and take care not to confound two stones of the same colour, but which may be very differently prized by the *virtuoso.*

Since it usually happens that the true gems are in a cut and polished state, or even set in gold or silver, we are thereby unable to apply to them the criteria of mineralogical and chemical science. The cutting of the stone has removed or masked its crystalline character, and circumstances rarely permit the phenomena of double or single refraction to be observed; while the test by the blowpipe is inadmissable. Hence the only scientific resources that remain are the trial by electricity, which is often inconclusive; the degree of hardness, a criterion requiring great experience in the person who employs it; and, lastly, the proof by specific gravity, unquestionably one of the surest means of distinguishing the really fine gems from ornamental stones of similar colour. This proof can be applied only to a stone that is not set; but the richer gems are usually dismounted when offered for sale.

This character of specific gravity may be applied by any person of common intelligence, with the aid of a small hydrostatic balance. If, for example, a stone of a fine crimson-red colour, be offered for sale, as an oriental ruby, the purchaser must ascertain if it be not a Siberian tourmaline, or ruby spinel. Supposing its weight in air to be 100 grains, if he finds it reduced to 69 grains, when weighed in water, he concludes that its bulk is equal to that of 31 grains of water, which is its loss of weight. Now, a real sapphire which weighs 100 grains in air, would have weighed 76·6 in water; a spinel ruby of 100 grains would have weighed 72·2 in water, and a Siberian tourmaline of 100 grains would have weighed only 69 grains in water. The quality of the stone in question is, therefore, determined beyond all dispute, and the purchaser may be thus protected from fraud.

The *sard* of the English jewellers (*Sardoine*, French) is a stone of the nature of agate, having an orange colour more or less deep, and passing by insensible shades into yellow, reddish, and brown; whence it has been agreed to unite under this denomination all the agates whose colour verges upon brown. It should be remarked, however, that the sard presents, in its interior and in the middle of its ground, concentric zones, or small nebulosities, which are not to be seen in the red cornelian, properly so called. The ancients certainly knew our sard, since they have left us a great many of them engraved, but they seem to have associated under the title *sarda* both the sardoine of the French, and our cornelians and calcedonies. Pliny says that the *sarda* came from the neighbourhood of a city of that name in Lydia, and from the environs of Babylon. Among the engraved sards which exist in the collection of antiques in the Bibliothèque Royale of Paris, there is an Apollo remarkable for its fine colour and great size. When the stone forms a part of the agate-onyx, it is called sardonyx. For further details upon Gems, and the art of cutting and engraving them, see LAPIDARY.

GEOGNOSY, means a knowledge of the structure of the earth; GEOLOGY, a description of the same. The discussion of this subject does not come within the province of this Dictionary.

GERHARDT'S ANHYDROUS ACETIC ACID. Mix perfectly dry fused acetate of potash with about half its weight of chloride of benzoyle, and applying a gentle heat, a limpid liquid distils over, which after being rectified has a constant boiling point of 2·79° Fahr., is heavier than water, with which it does not mix till after it has been agitated with it for some time. It dissolves at once in hot water, forming a hydrated acetic acid. Its composition agrees perfectly with the atomic numbers See Acid, Acetic.

GERMAN SILVER. See the latter end of the article Copper.

GERMINATION; (Eng. and Fr.; *Das Keimen*, Germ.) is the first sprouting of a seed after it is sown, or when, after steeping, it is spread upon the malt floor. See Beer.

GIG MACHINES, are rotatory drums, mounted with thistles or wire teeth for teazling cloth. See Woollen Manufacture.

GILDING (*Dorure*, Fr.; *Vergoldung*, Germ.); is the art of coating surfaces with a thin film of gold. For a full discussion of this subject, see Gold. Mr. Elkington, gilt toy maker, obtained a patent, in June, 1836, for gilding copper, brass, &c., by means of potash or soda combined with carbonic acid, and with a solution of gold. Dissolve, says he, 5 oz. troy of fine gold in 52 oz. avoirdupois of nitro-muriatic acid of the following proportions; viz. 21 oz. of pure nitric acid, of spec. grav. 1·45, 17 oz. of pure muriatic acid, of spec. grav. 1·15; with 14 oz. of distilled water.

The gold being put into the mixture of acids and water, they are to be heated in a glass or other convenient vessel till the gold is dissolved; and it is usual to continue the application of heat after this is effected, until a reddish or yellowish vapour ceases to rise.

The clear liquid is to be carefully poured off from any sediment which generally appears and results from a small portion of silver, which is generally found in alloy with gold. The clear liquid is to be placed in a suitable vessel of stone; pottery ware is preferred. Add to the solution of gold 4 gallons of distilled water, and 20 pounds of bicarbonate of potash of the best quality; let the whole boil moderately for two hours, the mixture will then be ready for use.

The articles to be gilded having been first perfectly cleaned from scale or grease, they are to be suspended on wires, conveniently for a workman to dip them in the liquid, which is kept boiling. The time required for gilding any particular article will depend on circumstances, partly on the quantity of gold remaining in the liquid, and partly on the size and weight of the article; but a little practice will readily give sufficient guidance to the workman.

Supposing the articles desired to be gilded be brass or copper buttons, or small articles for gilt toys, or ornaments of dress, such as ear-rings or bracelets, a considerable number of which may be strung on a hoop, or bended piece of copper or brass wire, and dipped into the vessel containing the boiling liquid above described, and moved therein, the requisite gilding will be generally obtained in from a few seconds to a minute; this is when the liquid is in the condition above described, and depending on the quality of the gilding desired; but if the liquid has been used some time, the quantity of gold will be lessened, which will vary the time of operating to produce a given effect, or the color required, all which will quickly be observed by the workman; and by noting the appearance of the articles from time to time, he will know when the desired object is obtained, though it is desirable to avoid as much as possible taking the articles out of the liquid.

When the operation is completed, the workman perfectly washes the articles so gilded with clean water; they may then be submitted to the usual process of coloring.

If the articles be cast figures of animals, or otherwise of considerable weight, compared with the articles above mentioned, the time required to perform the process will be greater.

In case it is desired to produce what is called a dead appearance, it may be performed by several processes: the one usually employed is to dead the articles in the process of cleaning, as practised by brass-founders and other trades; it is produced by an acid, prepared for that purpose, sold by the makers under the term "deading aquafortis," which is well understood.

It may also be produced by a weak solution of nitrate of mercury, applied to the articles previous to the gilding process, as is practised in the process of gilding with mercury, previous to spreading the amalgam, but generally a much weaker solution; or the articles having been gilded may be dipped in a solution of nitrate of mercury, and submitted to heat to expel the same, as is practised in the usual process of gilding.

It is desirable to remark, that much of the beauty of the result depends on the well cleaning of the articles, and it is better to clean them by the ordinary processes, and at once pass them into the liquid to be gilded. See Gold, towards the end.

GIN, or *Geneva*, from *Genievre* (juniper), is a kind of ardent spirits manufactured in Holland, and hence called Hollands gin in this country, to distinguish it from British gin. The materials employed in the distilleries of Schiedam, are two parts of unmalted rye from Riga, weighing about 54 lbs. per bushel, and one part of malted bigg, weighing about 37 lbs. per bushel. The mash tun, which serves also as the fermenting tun, has a capacity of nearly 700 gallons, being about five feet in diameter at the mouth, rather narrower at the bottom, and 4½ feet deep; the stirring apparatus is an oblong rectangular iron grid made fast to the end of a wooden pole. About a barrel, = 36 gallons of water, at a temperature of from 162° to 168° (the former heat being best for the most highly dried rye), are put into the mash tun for every 1½ cwt. of meal, after which the malt is introduced and stirred, and lastly the rye is added. Powerful agitation is given to the magma till it becomes quite uniform; a process which a vigorous workman piques himself upon executing in the course of a few minutes. The mouth of the tun is immediately covered over with canvas, and further secured by a close wooden lid, to confine the heat; it is left in this state for two hours. The contents being then stirred up once more, the *transparent* spent wash of a preceding mashing is first added, and next as much cold water as will reduce the temperature of the whole to about 85° F. The best Flanders yeast, which had been brought, for the sake of carriage, to a doughy consistence by pressure, is now introduced to the amount of one pound for every 100 gallons of the mashed materials.

The gravity of the fresh wort is usually from 33 to 38 lbs. per Dicas' hydrometer; and the fermentation is carried on from 48 to 60 hours, at the end of which time the attenuation is from 7 to 4 lbs., that is, the specific gravity of the supernatant wash is from 1·007 to 1·004.

The distillers are induced, by the scarcity of beer-barm in Holland, to skim off a quantity of the yeast from the fermenting tuns, and to sell it to the bakers, whereby they obstruct materially the production of spirit, though they probably improve its quality, by preventing its impregnation with yeasty particles; an unpleasant result which seldom fails to take place in the whiskey distilleries of the United Kingdom.

On the third day after the fermenting tun is set, the wash containing the grains is transferred to the still, and converted into low wines. To every 100 gallons of this liquor, two pounds of juniper berries, from 3 to 5 years old, being added along with about one quarter of a pound of salt, the whole are put into the low wine still, and the fine Holland spirit is drawn off by a gentle and well-regulated heat, till the magma becomes exhausted; the first and the last products being mixed together; whereby a spirit, 2 to 3 per cent. above our hydrometer proof, is obtained, possessing the peculiar fine aroma of gin. The quantity of spirit varies from 18 to 21 gallons per quarter of grain; this large product being partly due to the employment of the spent wash of the preceding fermentation; an addition which contributes at the same time to improve the flavour.

For the above instructive details of the manufacture of genuine Hollands, I am indebted to Robert More, Esq., formerly of Underwood, distiller, who, after studying the art at Schiedam, tried to introduce that spirit into general consumption in this country, but found the palates of our gin-drinkers too much corrupted to relish so pure a beverage.

GINGER BEER. Boil 65 gallons of river water, 1½ cwt. of the best loaf sugar, and 5 lbs. of the best race ginger, bruised, half an hour; then add the whites of 10 eggs, beaten to a froth with 2 ounces of dissolved isinglass. Stir it well in, and boil 20 minutes longer, skimming it the whole time. Then add the thin rinds of 50 lemons, boiling them 10 minutes more. Cut 28 lbs. of good Malaga raisins in half, take away the stones and stalks, and put them, with the juice of the lemon, strained, into the hogshead. Strain the hot liquor into a cooler, and when it has stood two hours and is settled, draw it off the lees, clear, and put it into the cask; filter the thick and fill up with it. Leave the bung out, and when at the proper temperature, stir 3 quarts of thick fresh ale yeast well into it; put on the bung lightly, and let it ferment 6 or 7 days, filling up with liquor as it ferments over. When the fermentation has ceased, pour in 6 quarts of French brandy, and 8 ounces of the best isinglass, dissolved in a gallon of the wine; then secure the bung effectually, and paste paper over it, &c. Keep it 2 years in a cool cellar, then bottle it, using the best corks, and sealing them; and when it is 4 years old commence using it.

GINNING, is the name of the operation by which the filaments of cotton are separable from the seeds. See Cotton Manufacture.

GLANCE COAL, or anthracite, of which there are two varieties, the *slaty* and the *conchoidal.* See Anthracite and Pitcoal.

GLASS (*Verre*, Fr.; *Glas*, Germ.); is a transparent solid formed by the fusion of siliceous and alkaline matter. It was known to the Phœnicians, and constituted for a long time an exclusive manufacture of that people, in consequence of its ingredients, natron, sand, and fuel, abounding upon their coasts. It is probable that the more ancient Egyptians were unacquainted with glass, for we find no mention of it in the writings of Moses. But according to Pliny and Strabo, the glass works of Sidon and Alexandria were famous in their times, and produced beautiful articles, which were cut, engraved, gilt, and stained of the most brilliant colours, in imitation of precious stones. The Romans employed glass for various purposes; and have left specimens in Herculaneum of window-glass, which must have been blown by methods analogous to

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the modern The Phœnician processes seem to have been learned by the Crusaders, and transferred to Venice in the 13th century, where they were long held secret, and formed a lucrative commercial monopoly. Soon after the middle of the 17th century, Colbert enriched France with the blown mirror glass manufacture.

Chance undoubtedly had a principal share in the invention of this curious fabrication, but there were circumstances in the most ancient arts likely to lead to it; such as the fusing and vitrifying heats required for the formation of pottery, and for the extraction of metals from their ores. Pliny ascribes the origin of glass to the following accident. A merchant ship laden with natron being driven upon the coast at the mouth of the river Belus, in tempestuous weather, the crew were compelled to cook their victuals ashore, and having placed lumps of the natron upon the sand, as supports to the kettles, found to their surprise masses of transparent stone among the cinders. The sand of this small stream of Galilee, which runs from the foot of Mount Carmel, was in consequence supposed to possess a peculiar virtue for making glass, and continued for ages to be sought after and exported to distant countries for this purpose.

Agricola, the oldest author who has written technically upon glass, describes furnaces and processes closely resembling those employed at the present day. Neri, Kunckel, Henckel, Pott, Achard, and some other chemists, have since then composed treatises upon the subject; but Neri, Bosc, Antic, Loysel, and Allut, in the Encyclopédie Methodique, are the best of the older authorities.

The window-glass manufacture was first begun in England in 1557, in Crutched Friars, London; and fine articles of flint-glass were soon afterwards made in the Savoy House, Strand. In 1635 the art received a great improvement from Sir Robert Mansell, by the use of coal fuel instead of wood. The first sheets of blown glass for looking-glasses and coach windows were made in 1673 at Lambeth, by Venetian artisans employed under the patronage of the Duke of Buckingham.

The casting of mirror-plates was commenced in France about the year 1688, by Abraham Thevart; an invention which gave rise soon afterwards to the establishment of the celebrated works of St. Gobain, which continued for nearly a century the sole place where this highly-prized object of luxury was well made. In cheapness, if not in excellence, the French mirror-plate has been for some time rivalled by the English.

The analysis of modern chemists, which will be detailed in the course of this article, and the light thrown upon the manufacture of glass in general by the accurate means now possessed of purifying its several ingredients, would have brought the art long since to the highest state of perfection in this country, but for the vexatious interference and obstructions of our excise laws.

The researches of Berzelius having removed all doubts concerning the acid character of silica, the general composition of glass presents now no difficulty of conception. This substance consists of one or more salts, which are silicates with bases of potash, soda, lime, oxide of iron, alumina, or oxide of lead; in any of which compounds we can substitute one of these bases for another, provided that one alkaline base be left. Silica in its turn may be replaced by the boracic acid, without causing the glass to lose its principal characters.

Under the title glass are therefore comprehended various substances fusible at a high temperature, solid at ordinary temperatures, brilliant, generally more or less transparent, and always brittle. The following chemical distribution of glasses has been proposed.

1. Soluble glass; a simple silicate of potash or soda; or both of these alkalis.
2. Bohemian or crown glass; silicate of potash and lime.
3. Common window and mirror glass; silicate of soda and lime; sometimes also of potash.
4. Bottle glass; silicate of soda, lime, alumina and iron.
5. Ordinary crystal glass; silicate of potash and lead.
6. Flint glass; silicate of potash and lead; richer in lead than the preceding.
7. Strass; silicate of potash and lead; still richer in lead.
8. Enamel; silicate and stannate or antimoniate of potash or soda, and lead.

The glasses which contain several bases are liable to suffer different changes when they are melted or cooled slowly. The silica is divided among these bases, forming new compounds in definite proportions, which by crystallizing separate from each other, so that the general mixture of the ingredients which constitute the glass is destroyed. It becomes then very hard, fibrous, opaque, much less fusible, a better conductor of electricity and of heat; forming what Reaumur styled *devitrified* glass; and what is called after him Reaumur's porcelain.

This altered glass can always be produced in a more or less perfect state, by melting the glass and allowing it to cool very slowly; or merely by heating it to the softening pitch, and keeping it at this heat for some time. The process succeeds best with the most complex vitreous compounds, such as bottle glass; next with ordinary window glass; and lastly with glass of potash and lead.

This property ought to be kept constantly in view in manufacturing glass. It shows why in making bottles we should fashion them as quickly as possible with the aid of a mould and reheat them as seldom as may be absolutely necessary. If it be often heated and cooled, the glass loses its ductility, becomes refractory, and exhibits a multitude of stony granulations throughout its substance. When coarse glass is worked at the enameller's lamp, it is apt to change its nature in the same way, if the workman be not quick and expert at his business.

From these facts we perceive the importance of making a careful choice of the glass intended to be worked in considerable masses, such as the large object glasses of telescopes; as their annealing requires a very slow process of refrigeration, which is apt to cause devitrified specks and clouds. For such purposes, therefore, no other species of glass is well adapted except that with basis of potash and lead; or that with basis of potash and lime. These two form the best flint glass, and crown glass; and they should be exclusively employed for the construction of the object glasses of achromatic telescopes. Crystal glass is rapidly corroded by the sulphate of ammonia at a heat of 600° Fahr.

The following is an account of the exports of British manufacture:—

		Quantities.		Declared Value.	
		1851.	1852.	1851.	1852.
Flint glass - - - - - -	cwts.	23,870	25,755	£106,500	£110,519
Window glass - - - - -	cwts.	15,517	16,460	20,077	22,234
Bottles, green or common -	cwts.	296,065	325,804	162,843	172,880
Plate glass - - - - - -	value	- -	- -	18,335	20,929

Imports and exports of Glass of Foreign and Colonial produce in the years ending respectively 5th January, 1851 and 1852:—

Window glass, not exceeding $\frac{1}{9}$ of an inch thick, and shades and cylinders: imports, 21,015 cwts. and 12,358 cwts.; exports, 11,604 cwts. and 2,059 cwts.; duty on imports, 1,656*l.* and 1,877*l.*

All glass exceeding $\frac{1}{9}$ of an inch thick, all silvered or polished glass of whatever thickness: imports, 122,394 sq. ft. and 173,935 sq. ft.; exports, 32,388 sq. ft. and 36,550 sq. ft.; duty received, 1,845*l.* and 2,841*l.*

White flint glass goods (except bottles) not cut, engraved, or otherwise ornamented: imports, 95,240 lbs. and 102,002 lbs.; exports, 70,660 lbs. and 66,738 lbs.; duty received, 101*l.* and 108*l.*

All flint cut glass, flint coloured glass, and fancy ornamental glass: imports, 880,981 lbs. and 682,011 lbs.; exports, 187,209 lbs. and 166,948 lbs.; duty received, 5,542*l.* and 4,454*l.*

GLASS-MAKING, *general principles of.* Glass may be defined in technical phraseology, to be a transparent homogeneous compound formed by the fusion of silica with oxides of the alkaline, earthy, or common metals. It is usually colourless, and then resembles rock crystal, but is occasionally stained by accident or design with coloured metallic oxides. At common temperatures it is hard and brittle, in thick pieces; in thin plates or threads, flexible and elastic; sonorous when struck; fracture conchoidal, and of that peculiar lustre called vitreous; at a red heat, becoming soft, ductile and plastic. Besides glass properly so called, other bodies are capable of entering into vitreous fusion, as phosphoric acid, boracic acid, arsenic acid, as also certain metallic oxides, as of lead, and antimony, and several chlorides; some of which are denominated glasses. Impure and opaque vitriform masses are called slags; such are the production of blast iron furnaces and many metallurgic operations.

Silica, formerly styled the earth of flints, which constitutes the basis of all commercial glass, is infusible by itself in the strongest fire of our furnaces; but its vitreous fusion is easily effected by a competent addition of potash or soda, either alone or mixed with lime or litharge. The silica, which may be regarded as belonging to the class of acids, combines at the heat of fusion with these bases, into saline compounds; and hence glass may be viewed as a silicate of certain oxides, in which the acid and the bases exist in equivalent proportions. Were these proportions, or the quantities of the bases which silica requires for its saturation at the melting point, exactly ascertained, we might readily determine beforehand the best proportions of materials for the glass manufacture. But as this is far from being the case, and as it is, moreover, not improbable that the capacity of saturation of the silica varies with the temperature, and that the properties of glass also vary with the bases, we must, in the present state of our knowledge, regulate the proportions rather by practice than by theory, though the latter may throw an indirect light upon the subject. For example, a good colourless glass has been found by analysis to consist of 72 parts of silica, 13 parts of potash, and 10 parts of lime, in 95 parts. If we reduce these numbers to the equivalent ratios, we shall have the following results; taking the atomic weights as given by Berzelius.

1 atom	potash =	590	14.67	
1	lime	356	8·84	
3	silica	1722	42·79	71·49
2	silica	1155	28·70	
		3823	95·00	

This glass would therefore have been probably better compounded with the just atomic proportions, to which it nearly approaches, viz. 71·49 silica, 14·67 potash, and 8·84 lime, instead of those given above as its actual constituents.

The proportions in which silica unites with the alkaline and other oxydes are modified by the temperature as above stated; the lower the heat, the less silica will enter into the glass, and the more of the base will in general be required. If a glass which contains an excess of alkali be exposed to a much higher temperature than that of its formation, a portion of the base will be set free to act upon the materials of the earthen pot, or to be dissipated in fumes, until such a silicate remains as to constitute a permanent glass corresponding to that temperature. Hence the same mixture of vitrifiable materials will yield very different results, according to the heats in which it is fused and worked in the glass-house; and therefore the composition should always be referrible to the going of the furnace. When a species of glass which at a high temperature formed a transparent combination with a considerable quantity of lime, is kept for some time in fusion at a lower temperature, a portion of the lime unites with the silica into another combination of a semi-vitreous or even of a stony aspect, so as to spoil the transparency of the glass altogether. There is probably a supersilicate and a sub-silicate formed in such cases; the latter being much the more fusible of the two compounds. The Reaumur's porcelain produced by exposing bottle glass to a red heat for 24 hours, is an example of this species of vitreous change, in which new affinities are exercised at a lower temperature. An excess of silica, caused by the volatilization of alkaline matter with too strong firing, will bring on similar appearances.

The specific gravity of glass varies from 2·3 to 3·6. That of least specific gravity consists of merely silica and potash fused together; that with lime is somewhat denser, and with oxyde of lead denser still. Plate glass made from silica, soda, and lime, has a specific gravity which varies from 2·50 to 2·6; crystal or flint glass from 3·0 to 3·6.

The power of glass to resist the action of water, alkalis, acids, air, and light, is in general the greater, the higher the temperature employed in its manufacture, the smaller the proportion of its fluxes, and the more exact the equivalent ratios of its constituents. When glass contains too much alkali, it is partially soluble in water. Most crystal glass is affected by having water boiled in it for a considerable time; but crown glass being poorer in alkali, and containing no lead, resists that action much longer, and is therefore better adapted to chemical operations. The affinity of glass for water, or its hygrometric attraction, is also proportional to the quantity of alkali which it contains. In general also potash glass is more apt to become damp than soda glass, agreeably to the respective hygrometric properties of these two alkalis, and also to the smaller proportion of soda than of potash requisite to form glass.

Air and light operate upon glass probably by their oxydizing property. Bluish or greenish colored glasses become by exposure colorless, in consequence undoubtedly of the peroxydizement of the iron, to whose protoxyde they owe their tint; other glasses become purple red from the peroxydizement of the manganese. The glasses which contain lead, suffer another kind of change in the air, if sulphureted hydrogen be present; the oxyde of lead is converted into a sulphuret, with the effect of rendering the surface of the glass opaque and iridescent. The more lead is in the glass, the quicker does this iridescence supervene. By boiling concentrated sulphuric acid in a glass vessel, or upon glass, we can ascertain its power of resisting ordinary menstrua. Good glass will remain smooth and transparent; bad glass will become rough and dim.

The brittleness of unannealed glass by change of temperature is sometimes very great. I have known a thick vessel to fly by vicissitudes of the atmosphere alone. This defect may be corrected by slowly heating the vessel in salt water or oil to the highest pitch consistent with the nature of these liquids, and letting it cool very slowly. Within the limits of that range of heat, it will, in consequence of this treatment, bear alternations of temperature without cracking as before.

It has been said that glass made from silica and alkalis alone will not resist the action of water but that the addition of a little lime is necessary for this effect. In general 100 parts of quartzose sand require 33 parts of dry carbonate of soda for their vitrification, and 45 parts of dry carbonate of potash. But to make unchangeable alkaline glass, especially with potash, a smaller quantity of this than the above should be used, with a very violent heat. A small proportion of lime increases the density, hardness, and lustre of glass; and it aids in decomposing the alkaline sulphates and muriates always present in the pearlash of commerce. From 7 to 20 parts of dry slaked lime have been added for 100 of silica, with advantge, it is said, in some German glass manufactories, where the alkaline matter is soda; for potash does not assimilate well with the calcareous earth.

In many glass works on the Continent, sulphate of soda is the form under which alkaline matter is introduced into glass. This salt requires the addition of 8 per cent. of charcoal to decompose and dissipate its acid; a result which takes place at a high heat, without the addition of any lime. 88 pounds of quartz-sand, 44 pounds of dry glauber salt, and 3 pounds of charcoal, properly mixed and fused, afford a limpid, fluent, and workable glass; with the addition of 17 pounds of lime these materials fuse more readily into a plastic mass. If less carbon be added, the fusion becomes more tedious. The two following formulæ afford good glauber salt glass.

	1.	2.
Sand - - - - - - - -	100	60·2
Calcined sulphate of soda - -	50	26·8
Lime - - - - - - -	20	10·8
Charcoal - - - - - -	2·65	2·1

The first mixture has been proved in the looking-glass manufactory of Neuhaus near Vienna, and the second by the experiments of Kirn. The fusion of the first requires 18, of the second 21 hours. The bluish green tinge which these otherwise beautiful and brilliant glasses possess, is not removeable by the ordinary means, such as manganese or arsenic, which decolor alkaline glass. When the sulphate of soda and charcoal are used in smaller proportions, the glass becomes more colorless. The tinge is no doubt owing to the sulphur combining with the oxyde of sodium, in some such way as in the pigment *ultramarine.*

By a proper addition of galena (the native sulphuret of lead), to glauber salt and quartz sand, without charcoal, it is said a tolerably good crystal glass may be formed. The sulphuric acid of the salt is probably converted by the reaction of the sulphuret of lead into sulphurous acid gas, which is disengaged.

One atom of sulphuret of lead = 1495·67, is requisite to decompose 3 atoms of sulphate of soda = 2676. It is stated, on good authority, that a good colorless glass may be obtained by using glauber salt without charcoal, as by the following formula.

Quartz-sand - - - -	100 pounds
Calcined glauber salt - -	24
Lime - - - - - -	20
Cullet of soda glass - -	12

The melting heat must be continued for 26½ hours. A small quantity of the sand is reserved to be thrown in towards the conclusion of the process, in order to facilitate the expulsion of air bubbles. The above mixture will bear to be blanched by the addition of manganese and arsenic. The decomposition of the salt is in this case effected by the lime, with which the sulphuric acid first combines, is then converted into sulphurous acid, and dissipated. Glass made in this way was found by analysis to consist of 79 parts of silica, 12 lime, and 9·6 soda, without any trace of gypsum or sulphuric acid.

Glauber salt is partially volatilized by the heat of the furnace, and acts upon the arch of the oven and the tops of the pots. This is best prevented by introducing at first into the pots the whole of the salt mixed with the charcoal, the lime, and one fourth part of the sand; fusing this mixture at a moderate heat, and adding gradually afterwards the remainder of the sand, increasing the temperature at the same time. If we put in the whole ingredients together, as is done with potash glass, the sand and lime soon fall to the bottom, while the salt rises to the surface, and the combination becomes difficult and unequal.

Sulphate of potash acts in the same way as sulphate of soda.

Muriate of soda also, according to Kirn, may be used as a glass flux with advantage. The most suitable proportions are 4 parts of potash, 2 of common salt, and 3 of lime, agreeably to the following compositions:—

	1.	2.
Quartz-sand - - - - - -	60·0	75·1
Calcined carbonate of potash - -	17·8	19·1
Common salt - - - - - -	8·9	9·5
Lime - - - - - - -	13·3	14·3

For No. 1., the melting heat must be 10 hours, which turns out a very pure, solid, good glass; for No. 2., 23 hours of the furnace are required. Instead of the potash, glauber salt may be substituted; the proportions being then 19·1 glauber salt, 9·5 muriate of soda, 14·3 lime, 75·1 sand, and 1·3 charcoal.

The oxide of lead is an essential constituent of the denser glasses, and may be regarded as replacing the lime, so as to form with the quartz-sand a silicate of lead. It assimilates best with purified pearl ash, on account of the freedom of this alkali from iron, which is present in most sodas.

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Its atomic constitution may be represented as follows:—

				Computation.	Analysis.
Silicic acid - - - - - -	5 atoms	=	2877·	59·19	59·20
Oxide of lead - - - - -	1	=	1394·5	28·68	28.20
Potash - - - - - - - -	1	=	590·0	12·13	9·00
Oxides of iron and manganese			—	—	1·40
			4861·5	100·00	100·00

The above analysis by Berthier relates to a specimen of the best English crystal glass, perfectly colourless and free from air-bubbles. This kind of glass may however take several different proportions of potash and silica to the oxide of lead.

The composition of mirror-plate, as made on the Continent, is as follows:—

White quartz-sand - - - - - -	300	pounds
Dry carbonate of soda - - - - - -	100	
Lime slaked in the air - - - - - -	43	
Cullet, or old glass - - - - - -	300	

The manganese should not exceed one-half per cent. of the weight of soda.

Optical glass requires to be made with very peculiar care. It is of two different kinds; namely, *crown glass* and *flint glass.* The latter contains a considerable proportion of lead, in order to give it an increased dispersive power upon the rays of light, in proportion to its mean refractive power.

Optical crown glass should be perfectly limpid, and have so little colour, that a pretty thick piece of it may give no appreciable tinge to the rays of light. It should be exempt from striæ or veins as well as air-bubbles, and have not the slightest degree of milkiness. It should moreover preserve these qualities when worked in considerable quantities. Potash is preferable to soda for making optical crown glass, because the latter alkali is apt to make a glass which devitrifies and becomes opalescent, by long exposure to heat in the annealing process. A simple potash silicate would be free from this defect, but it would be too attractive of moisture, and apt to decompose eventually by the humidity of the atmosphere. It should therefore contain a small quantity of lime, and as little potash as suffices for making a perfect glass at a pretty high temperature. It is probably owing to the high heats used in the English crown glass works, and the moderate quantity of alkali (soda) which is employed, that our crown glass has been found to answer so well for optical purposes.

The following recipe for crown glass is excellent:—

5 atoms of silica (2½?) - - - - -	80
1 carbonate of soda - - - - - -	54
5 silica - - - - - - -	80
1 carbonate of lime - - - - - -	50
1 atom of carbonate of baryta - - - -	98
5 atoms of silica - - - - - -	80

Silicates of lime and baryta per se, or even combined, are very refractory; but they vitrify well along with a third silicate, such as that of soda, or potash.

Practical Details of the Manufacture of Glass.

The Venetians were the first in modern times who attained to any degree of excellence in the art of working glass, but the French became eventually so zealous of rivalling them, particularly in the construction of mirrors, that a decree was issued by the court of France, declaring not only that the manufacture of glass should not derogate from the dignity of a nobleman, but that nobles alone should be masters of glass-works. Within the last 30 or forty years, Great Britain has made rapid advances in this important art, and at the present day her pre-eminence in every department hardly admits of dispute.

There are five different species of glass, each requiring a peculiar mode of fabrication, and peculiar materials: 1. The coarsest and simplest form of this manufacture is *bottle* glass. 2. Next to it in cheapness of material may be ranked *broad* or *spread window glass.* An improved article of this kind is now made near Birmingham, under the name of British or German plate. 3. Crown glass comes next, or window glass, formed in large circular plates or discs. This glass is peculiar to Great Britain. 4. Flint glass, crystal glass, or glass of lead. 5. Plate or fine mirror glass.

The materials of every kind of glass are vitrified in pots made of a pure refractory clay; the best kind of which is a species of shale or slate clay dug out of the coal-formation near Stourbridge. It contains hardly any lime or iron, and consists of silica and alumina in nearly equal proportions. The masses are carefully picked, brushed, and ground under edge iron wheels of considerable weight, and sifted through sieves having 20 meshes in the square inch. This powder is moistened with water (best hot) and kneaded by the feet or a loam-mill into a uniform smooth paste. A large body of this dough should be made up at a time, and laid by in a damp cellar to ripen. Previously to working it into shapes, it should be mixed with about a fourth of its weight of cement of old pots, ground to powder. This mixture is sufficiently plastic, and being less contractile by heat, forms more solid and durable vessels. Glass-house pots have the figure of a truncated cone, with the narrow end undermost; those for bottle and window-glass being open at top, about 30 inches diameter at bottom, 40 inches at the mouth, and 40 inches deep; but the flint-glass pots are covered in at top with a dome-cap, having a mouth at the side, by which the materials are introduced, and the glass is extracted. Bottle and crown-house pots are from 3 to 4 inches thick; those for flint-houses are an inch thinner, and of proportionally smaller capacity.

The well-mixed and kneaded dough is first worked upon a board into a cake for the bottom; over this the sides are raised, by laying on its edges rolls of clay above each other with much manual labor, and careful condensation. The clay is made into lumps, is equalized, and slapped much in the same way as for making Pottery. The pots thus fashioned must be dried very prudently, first in the atmospheric temperature, and finally in a stove floor, which usually borrows its heat directly from the glass-house. Before *setting the pots* in the furnace, they are annealed during 4 or 5 days, at a red heat, in a small reverberatory vault, made on purpose. When completely annealed, they are transferred with the utmost expedition into their seat in the fire, by means of powerful tongs supported on the axle of an iron-wheel carriage frame, and terminating in a long lever for raising them and swinging them round. The *pot-setting* is a desperate service, and when unskilfully conducted without due mechanical aids, is the forlorn hope of the glass-founder.—*Quæque ipse miserrima vidi.* The celebrated chemist, Dr. Irvine, caught his last illness by assisting imprudently at this formidable operation. The working breast of the hot furnace must be laid bare so as to open a breach for the extraction of the faulty pot, and the insertion of the fresh one, both in a state of bright incandescence. It is frightful to witness the eyes and fuming visages of the workmen, with the blackening and smoking of their scorched woollen clothes, exposed so long to the direct radiations of the flame. A light mask and sack dress coated with tinfoil, would protect both their faces and persons from any annoyance, at a very cheap rate.

The glass-houses are usually built in the form of a cone, from 60 to 100 feet high, and from 50 to 80 feet in diameter at the base. The furnace is constructed in the centre of the area, above an arched or groined gallery which extends across the whole space, and terminates without the walls, in large folding doors. This cavern must be sufficiently high to allow laborers to wheel out the cinders in their barrows. The middle of the vaulted top is left open in the building, and is covered over with the grate-bars of the furnace.

1. *Bottle glass.*—The bottle-house and its furnace resemble nearly *fig.* 505. The furnace is usually an oblong square chamber, built of large fire-bricks, and arched over with fire-stone, a silicious grit of excellent quality extracted from the coal measures of Newcastle. This furnace stands in the middle of the area; and has its base divided into three compartments. The central space is occupied by the grate-bars; and on either side is the platform or fire-brick *siege* (seat), raised about 12 inches above the level of the ribs upon which the pots rest. Each *siege* is about 3 feet broad.

In the sides of the furnace, semi-circular holes of about a foot diameter are left opposite to, and a little above the top of, each pot, called working holes, by which the workmen shovel in the materials, and take out the plastic glass. At each angle of the furnace there is likewise a hole of about the same size, which communicates with the calcining furnace of a cylindrical form, dome-shaped at top. The flame that escapes from the founding or pot-furnace is thus economically brought to reverberate on the raw materials of the bottle-glass, so as to dissipate their carbonaceous or volatile impurities, and convert them into a frit. A bottle-house has generally eight other furnaces or fire-arches; of which six are used for annealing the bottles after they are blown, and two for annealing the pots, before setting them in the furnace.

The laws of this country till lately prohibited the use for making common bottles of any fine materials. Nothing but the common river sand, and soap-boilers' waste, was allowed. About 3 parts of waste, consisting of the insoluble residuum of kelp, mixed with lime and a little saline substance, were used for 1 part of sand. This waste was first of all calcined in two of the fire arches or reverberatories reserved for that purpose, called the coarse arches, where it was kept at a red heat, with occasional stirring, from 24 to 30 hours, being the period of a journey or *journée*, in which the materials could be melted and worked into bottles. The roasted soap-waste was then withdrawn, under the name of ashes, from its arch, coarsely ground, and mixed with its proper proportion of sand. This mixture was now put into the fine arch, and calcined during the working journey, which extended to 10 or 12 hours. Whenever the pots were worked out, that frit was immediately transferred into them in its ignited state, and the founding process proceeded with such despatch that this first charge of materials was completely melted down in 6 hours, so that the pots might admit to be filled up again with the second charge of frit, which was founded in 4 hours more. The heat was briskly continued, and in the course of from 12 to 18 hours, according to the size of the pots, the quality of the fuel, and the draught of the furnace, the vitrification was complete. Before blowing the bottles, however, the glass must be left to settle, and to cool down to the blowing consistency, by shutting the *cave* doors and feeding holes, so as to exclude the air from the fire-grate and the bottom of the hearth. The glass or metal becomes more dense, and by its subsidence throws up the foreign lighter earthy and saline matters in the form of a scum on the surface, which is removed with skimming irons. The furnace is now charged with coal, to enable it to afford a working heat for 4 or 5 hours, at the end of which time more fuel is cautiously added, to preserve adequate heat for finishing the *journey*.

It is hardly possible to convey in words alone a correct idea of the manipulations necessary to the formation of a wine bottle; but as the manufacturers make no mystery of this matter, any person may have an opportunity of inspecting the operation. Six people are employed at this task; one, called a gatherer, dips the end of an iron tube, about five feet long, previously made red-hot, into the pot of melted *metal*, turns the rod round so as to surround it with glass, lifts it out to cool a little, and then dips and turns it round again; and so in succession till a ball is formed on its end sufficient to make the required bottle. He then hands it to the blower, who rolls the plastic lump of glass on a smooth stone or cast-iron plate, till he brings it to the very end of the tube; he next introduces the pear-shaped ball into an open brass or cast-iron mould, shuts this together by pressing a pedal with his foot, and holding his tube vertically, blows through it, so as to expand the cooling glass into the form of the mould. Whenever he takes his foot from the pedal-lever, the mould spontaneously opens out into two halves, and falls asunder by its bottom hinge. He then lifts the bottle up at the end of the rod, and transfers it to the finisher, who, touching the glass tube at the end of the pipe with a cold iron, cracks off the bottle smoothly at its mouth-ring. The finished bottles are immediately piled up in the hot annealing arch, where they are afterwards allowed to cool slowly for 24 hours at least. See BOTTLE MOULD.

2. *Broad or spread window-glass.*—This kind of glass is called *inferior* window-glass, in this country, because coarse in texture, of a wavy wrinkled surface, and very cheap, but on the Continent *spread* window-glass, being made with more care, is much better than ours, though still far inferior in transparency and polish to crown glass, which has, therefore, nearly superseded its use among us. But Messrs. Chance and Hartley, of West Bromwich near Birmingham, have of late years mounted a spread-glass work, where they make *British sheet glass*, upon the best principles, and turn out an article quite equal, if not superior, to anything of the kind made either in France or Belgium. Their materials are those used in the crown-glass manufacture. The vitrifying mixture is fritted for 20 or 30 hours in a reverberatory arch, with considerable stirring and puddling with long-handled shovels and rakes; and the frit is then transferred by shovels, while red hot, to the melting pots to be founded. When the glass is rightly vitrified, settled, and brought to a working heat, it is lifted out by iron tubes, as will be described under the article CROWN GLASS, blown into pears, which being elongated into cylinders, are cracked up along one side, parallel to the axis, by touching them with a cold iron dipped in water, and are then opened out into sheets. Glass cylinders are spread in France, and at West Bromwich, on a bed of smooth stone Paris-plaster, or laid on the bottom of a reverberatory arch; the cylinder being placed on its side horizontally, with the cracked line uppermost, gradually opens out, and flattens on the hearth. At one time, thick plates were thus prepared for subsequent polishing into mirrors; but the glass was never of very good quality; and this mode of making mirror-plate has accordingly been generally abandoned.

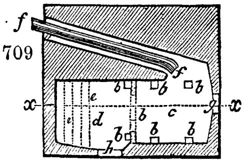
The spreading furnace or oven is that in which cylinders are expanded into tables or plates. It ought to be maintained at a brisk red heat, to facilitate the softening of the glass. The oven is placed in immediate connexion with the annealing arch, so that the tables may be readily and safely transferred from the former to the latter. Sometimes the cylinders are spread in a large muffle furnace, in order to protect them from being tarnished by sulphureous and carbonaceous fumes.

Fig. 709 represents a ground plan of both the spreading and annealing furnace; *fig.* 710 is an oblong profile in the direction of the dotted line x x, *fig.* 709.

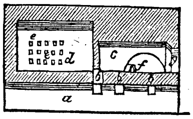
a is the fire-place; *b b* the canals or flues through which the flame rises into both furnaces; *c* the spreading furnace, upon whose sole is the spreading slab. *d* is the cooling and annealing oven; *e e* iron bars which extend obliquely across the annealing arch, and serve for resting the glass tables against, during the cooling. *f f* the channel along which the previously cracked cylinders are slid, so as to be gradually warmed;

g the opening in the spreading furnace, for enabling the workmen to regulate the pro

709



710

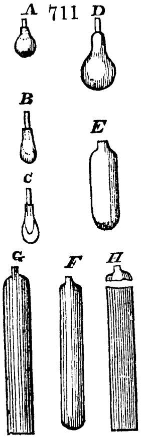


cess; h a door in the annealing arch, for introducing the tools requisite for raising up and removing the tables.

In forming glass-plates by the extension of a cylinder into a plane, the workman first blows the lump of glass into the shape of an oblong pear, the length of which must be nearly equal to the length of the intended plate, and its diameter such, that the circumference, when developed, will be equal to the breadth of the plate. He now rests the blowing iron on a stool or iron bar, while an assistant, with a pointed iron, pierces a hole into the extreme end of the pear, in the line of the blowing-pipe. This opening is then enlarged, by introducing the blade of a pair of spring-tongs, while the glass is turned round; and by skilful management, the end of the pear is eventually opened out into a cylindrical mouth. The workman next mounts upon a stool, and holds the blowing-iron perpendicularly. The blown cylinder is now cracked off, a punto rod of iron having been previously stuck to its one end, to form a spindle for working the other by. This rod has a flat disc on its end, or three prongs, which being dipped in melted glass, are applied to the mouth of the cylinder. By this as a handle, the glass cone is carried to the fire, and the narrow end being heated, is next opened by spring tongs, and formed into a cylinder of the same size as the other end. The cylinder, thus equalized, is next cracked or slit down in its side with a pair of shears, laid on a smooth copper plate, detached from the iron rod, spread out by heat into a plane surface, and finally annealed. This series of transformations is represented in *fig.* 711, at A, B, C, D, E, F, G, H.

Figs. 712 and 713 represent a Bohemian furnace in which excellent white window glass is founded. *Fig.* 712 is a longitudinal section of the glass and annealing furnace. *Fig.* 713 is the ground plan. *a* is the ash-pit vaulted under the sole of the furnace; the fire-place itself is divided into three compartments; with a middle slab at *d*, which is hollowed in the centre, for collecting any split glass, and two hearth tiles or slabs *b b*. *c c* are the draught or air holes; *e e* are arches upon which the bearing slabs *f f* partly rest. In the middle between these arches, the flame strikes upwards upon the pots *g g*, placed as closely together as possible, for economy of room. *h* is the breast wall of the furnace; *i*, *fig.* 713, the opening through which the pots are introduced; it is bricked up as soon as they are set. *k k*, is the base of the cone or dome of the furnace; *l l l*, the working orifices, which are made larger or smaller according to the size of the glass articles to be made. *m* is the flue which leads to the annealing stove *n*, with an arched door. Exterior to this, there is usually a drying kiln not shown in the figure; and there are adjoining stoves called *arches*, for drying and annealing the new pots before they are set.

711



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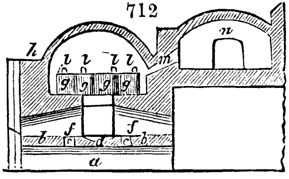

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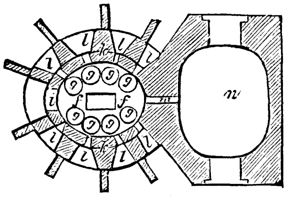


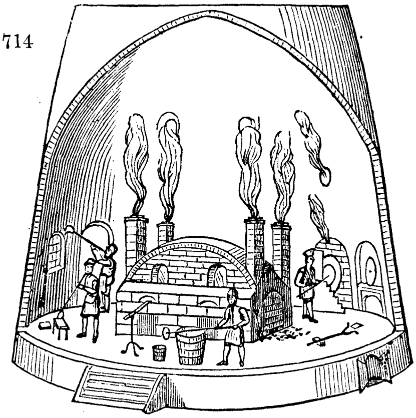
The cooling or annealing arch, or leer, is often built independent of the glass-house furnace, is then heated by a separate fire-place, and constructed like a very long reverberatory furnace. See Copper.

The leer pans or trays of sheet-iron, are laid upon its bottom in an oblong series, and hooked to each other.

3. *Crown-glass.*—The crown-glass house with its furnace is represented in *fig.* 714, where the *blowing* operation is shown on the one side of the figure, and the *flashing* on the other. The furnace is usually constructed to receive 4 or 6 pots, of such dimensions as to make about a ton of glass each at a time. There are, however, several sub-

sidiary furnaces to a crown-house. 1. A reverberatory furnace or *calcar*, for calcining o fritting the materials; 2. a blow ing furnace, for blowing the pear-shaped balls, made at the pot-holes, into large globes; 3. a flashing furnace, and bottoming hole for communicating a softening heat, in expanding the globe into a circular plate; 4. the annealing arch for the finished tables; 5. the reverberatory oven for annealing the pots prior to their being set upon the founding *siege*.

714



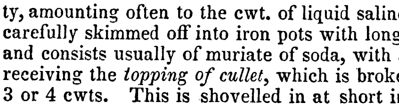
The materials of crown glass used to be, fine sand, by measure 5 parts, or by weight 10; ground kelp by measure 11 parts, or by weight 16½; but instead of kelp, soda ash is now generally employed. From 6 to 8 cwts. of sand, lime, and soda-ash, mixed together in wooden boxes with a shovel, are thrown on the sole of a large reverberatory, such as is represented in the article Copper. Here the mixture is well worked together, with iron paddles, flat shovels, and rakes with long handles; the area of this furnace being about 6 feet square, and the height 2 feet. The heat soon brings the materials to a pasty consistence, when they must be diligently turned over, to favor the dissipation of the carbon, sulphur, and other volatile matters of the kelp or soda ash, and to incorporate the fixed ingredients uniformly with the sand. Towards the end of three hours, the fire is considerably raised, and when the fourth hour has expired, the fritting operation is finished. The mass is now shovelled or raked out into shallow cast-iron square cases, smoothed down, and divided, before it hardens by cooling, into square lumps, by cross sections with the spade. These frit-bricks are afterwards piled up in a large apartment for use; and have been supposed to improve with age, by the efflorescence of their saline constituents into carbonate of soda on their surface.

The founding-pots are filled up with these blocks of frit, and the furnace is powerfully urged by opening all the subterranean passages to its grate, and closing all the doors and windows of the glass-house itself. After 8 or 10 hours the vitrification has made such progress, and the blocks first introduced are so far melted down, that another charge of frit can be thrown in, and thus the pot is fed with frit till the proper quantity is used. In about 16 hours the vitrification of the frit has taken place, and a considerable quantity, amounting often to the cwt. of liquid saline matter, floats over the glass. This salt is carefully skimmed off into iron pots with long ladles. It is called Sandiver or Glass-gall, and consists usually of muriate of soda, with a little sulphate. The pot is now ready for receiving the *topping of cullet*, which is broken pieces of window glass, to the amount of 3 or 4 cwts. This is shovelled in at short intervals; and as its pressure forces up the residuary saline matter, this is removed; for were it allowed to remain, the body of the glass would be materially deteriorated.

The heat is still continued for several hours till the glass is perfect, and the extrication of gas called the *boil*, which accompanies the fusion of crown glass, has nearly terminated, when the fire is abated, by shutting up the lower vault doors and every avenue to the grate, in order that the glass may settle fine. At the end of about 40 hours altogether, the fire being slightly raised by adding some coals, and opening the doors, the glass is carefully skimmed, and the working of the pots commences.

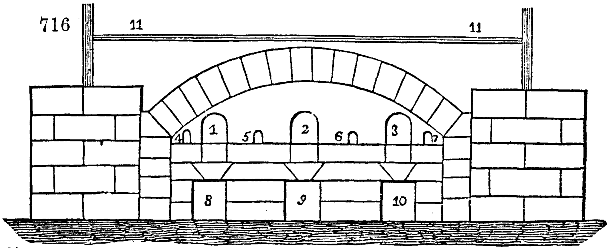
Before describing it, however, we may state that the marginal figure 715 shows the base of the crown-house cone, with the four open pots in two ranges on opposite sides of the furnace, sitting on their raised *sieges*, at each side of the grate. At one side of the base the door of the vault is shown, and its course is marked by the dotted lines.

715



Detailed description of the crown-glass furnace, figs. 716, 717.—It is an oblong square, built in the centre of a brick cone, large enough to contain within it, two or three pots at each side of the grate room, which is either divided as shown in the plan, or runs the whole length of the furnace, as the manufacturer chooses. *Fig.* 717 is a ground plan, and *fig.* 716 a front elevation, of a six-pot furnace. 1, 2, 3, *fig.* 717, are the working holes for the purposes of ventilation, of putting in the materials, and of taking out the metal to be wrought. 4, 5, 6, 7, are pipe holes for warming the pipes before beginning to work with them. 8, 9, 10, are foot holes for mending the pots and sieges. 11 is a bar of iron for binding the furnace, and keeping it from swelling.

716



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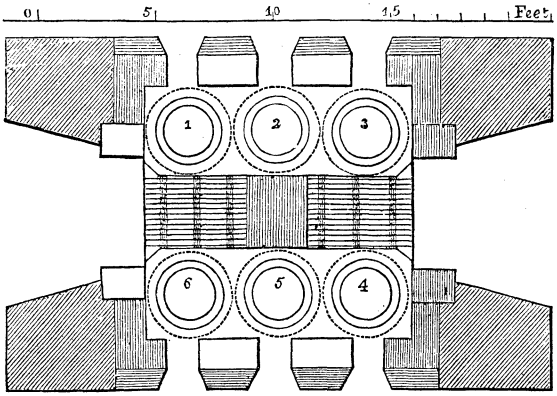


The arch is of an elliptic form; though a barrel arch, that is, an arch shaped like the half of a barrel cut longwise through the centre, is sometimes used. But this soon gives way when used in the manufacture of crown glass, although it does very well in the clay-furnace used for bottle houses.

The best stone for building furnaces is fire-stone, from Coxgreen in the neighborhood of Newcastle. Its quality is a close grit, and it contains a greater quantity of talc than the common fire-stone, which seems to be the chief reason of its resisting the fire better. The great danger in building furnaces is, lest the cement at the top should give way with the excessive heat, and by dropping into the pots, spoil the metal. The top should therefore be built with stones only, as loose as they can hold together after the centres are removed, and without any cement whatever. The stones expand and come quite close together when annealing; an operation which takes from eight to fourteen days at most. There is thus less risk of any thing dropping from the roof of the furnace.

The inside of the square of the furnace is built either of Stourbridge fire-clay annealed, or the Newcastle fire-stone, to the thickness of sixteen inches. The outside is built of common brick about nine inches in thickness.

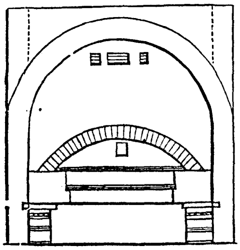
The furnace is thrown over an ash-pit, or cave, as it is called, which admits the atmospheric air, and promotes the combustion of the furnace. This cave is built of stone until it comes beneath the grate room, when it is formed of fire-brick. The abutments are useful for binding and keeping the furnace together, and are built of masonry. The furnaces are stoutly clasped with iron all round, to keep them tight. In four-pot furnaces this is unnecessary, provided there be four good abutments.

Fig. 718 is an elevation of the flashing furnace. The outside is built of common brick, the inside of fire-brick, and the mouth or nose of Stourbridge fire-clay.

Fig. 719 is the annealing kiln. It is built of common brick, except round the grate room, where fire-brick is used.

Few tools are needed for blowing and flashing crown-glass. The requisite ball of plastic glass is gathered, in successive layers as for bottles, on the end of an iron tube, and rolled into a pear-shape, on a cast-iron plate; the workman taking care that the air blown into its cavity is surrounded with an equal body of glass, and if he perceives any side to be thicker than another, he corrects the inequality by rolling it on the sloping iron table called marver, (marbre). He now heats the bulb in the fire, and rolls it so a to form the glass upon the end of the tube, and by a dexterous swing or two he lengthens it, as shown in I, *fig.* 720. To extend the neck of that pear, he next rolls it over a smooth iron rod, turned round in a horizontal direction, into the shape K, *fig.* 720. By further expansion at the blowing-furnace, he now brings it to the shape L, represented in *fig.* 720.

719



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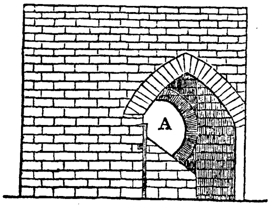
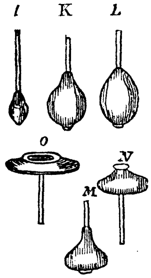




720

This spheroid having become cool and somewhat stiff, is next carried to the bottoming hole (like *fig.* 718), to be exposed to the action of flame. A slight wall erected before one half of this hole, screens the workman from the heat, but leaves room for the globe to pass between it and the posterior wall. The blowing-pipe is made to rest a little way from the neck of the globe, on a hook fixed in the front wall; and thus may be made easily to revolve on its axis, and by giving centrifugal force to the globe, while the bottom of it, or part opposite to the pipe, is softened by the heat, it soon assumes the form exhibited in M, *fig.* 720.

In this state the flattened globe is removed from the fire, and its rod being rested on the *casher box* covered with coal cinders, another workman now applies the end of a solid iron rod tipped with melted glass, called a *punto*, to the nipple or prominence in the middle; and thus attaches it to the centre of the globe, while the first workman cracks off the globe by touching its tubular neck with an iron chisel dipped in cold water. The workman having thereby taken possession of the globe by its bottom or knobbed pole attached to his punty rod, he now carries it to another circular opening, where he exposes it to the action of moderate flame with regular rotation, and thus slowly heats the thick projecting remains of the former neck, and opens it slightly out, as shown at N, in *fig.* 720. He next hands it to the *flasher*, who, resting the iron rod in a hook placed near the side of the orifice A, *fig.* 718, wheels it rapidly round opposite to a powerful flame, till it assumes first the figure O, and finally that of a flat circular table.

The flasher then walks off with the table, keeping up a slight rotation as he moves along, and when it is sufficiently cool, he turns down his rod into a vertical position, and lays the table flat on a dry block of fire-clay, or bed of sand, when an assistant nips it off from the *punto* with a pair of long iron shears, or cracks it off with a touch of cold iron. The loose table or plate is lastly lifted up horizontally on a double pronged iron fork, introduced into the annealing arch *fig.* 719 and raised on edge; an assistant with a long-kneed fork preventing it from falling too rapidly backwards. In this arch a great many tables of glass are piled up in iron frames, and slowly cooled from a heat of about 600° to 100° F., which takes about 24 hours; when they are removed. A circular plate or table of about 5 feet diameter weighs on an average 9 pounds.

4. *Flint glass.*—This kind of glass is so called because originally made with calcined flints, as the silicious ingredient. The materials at present employed in this country for the finest flint glass or crystal, are first, Lynn sand, calcined, sifted, and washed; second, an oxyde of lead, either red lead or litharge; and third, pearlash. The pearlash of commerce must however be purified by digesting it in a very little hot water, which dissolves the carbonate of potash, and leaves the foreign salts, chiefly sulphate of potash, muriate of potash, and muriate of soda. The solution of the carbonate being allowed to cool and become clear in lead pans, is then run off into a shallow iron boiler, and evaporated to dryness. Nitre is generally added as a fourth ingredient of the body of the glass; and it serves to correct any imperfections which might arise from accidental combustible particles, or from the lead being not duly oxydized. The above four substances constitute the main articles; to which we may add arsenic and manganese, introduced in very small quantities, to purify the color and clear up the transparency of the glass. The black oxyde of manganese, when used in such quantity only as to peroxydize the iron of the sand, simply removes the green tinge caused by the iron; but if more manganese be added than accomplishes that purpose, it will give a purple tinge to the glass; and in fact, most manufacturers prefer to have an excess rather than a defect of manganese, since cut glass has its brilliancy increased by a faint lilach hue. The arsenic is supposed to counteract the injury arising from excess of manganese, but is itself very apt on the other hand to communicate some degree of opalescence

or at least, to impair the lustre of the glass. When too much manganese has been added, the purple tinge may indeed be removed by any carbonaceous matter, as by thrusting a wooden rod down into the liquid glass; but this cannot be done with good effect in practice, since the final purple tinge is not decided till the glass is perfectly formed, and then the introduction of charcoal would destroy the uniformity of the whole contents of the pot.

The raw materials of flint glass are always mixed with about a third or a fourth of their weight of broken crystal of like quality; this mixture is thrown into the pot with a shovel; and more is added whenever the preceding portions by melting subside; the object being to obtain a pot full of glass, to facilitate the skimming off the impurities and sandiver. The mouth of the pot is now shut, by applying clay-lute round the stopper, with the exception of a small orifice below, for the escape of the liquid saline matter. Flint glass requires about 48 hours for its complete vitrification, though the materials be more fusible than those of crown glass; in consequence of the contents of the pot being partially screened by its cover from the action of the fire, as also from the lower intensity of the heat.

721

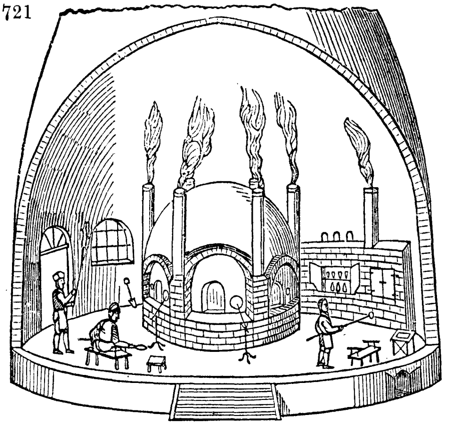
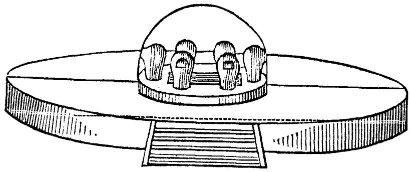


Fig. 721 represents a flint glass house for 6 pots, with the arch or leer on one side for annealing the crystal ware. In *fig.* 722, the base of the cone is seen, and the glass pots *in situ* on their platform ranged round the central fire grate. The dotted line denotes the contour of the furnace, *fig.* 721.

722



Whenever the glass appears fine, and is freed from its air bubbles, which it usually is in about 36 hours, the heat is suffered to fall a little by closing the bottom valves, &c., that the pot may settle; but prior to working the metal the heat is *somewhat raised* again.

It would be useless to describe the manual operations of fashioning the various articles of the flint-glass manufacture, because they are indefinitely varied to suit the conveniences and caprices of human society.

Every different flint-house has a peculiar proportion of glass materials. The following have been offered as good practical mixtures.

1.	Fine white sand - - - - - - -	300 parts.
	Red lead or litharge - - - - - -	200
	Refined pearlashes - - - - - -	80
	Nitre - - - - - - - - - -	20
	Arsenic and manganese, a minute quantity.	

In my opinion, the proportion of lead is too great in the above recipe, which is given on the authority of Mr. James Geddes, of Leith. The glass made with it would be probably yellowish and dull.

2.	Fine sand - - - - - - - - -	50·5
	Litharge - - - - - - - - - -	27·2
	Refined pearlashes (carbonate of potash, with 5 per cent. of water)	17·5
	Nitre - - - - - - - -	4·8
		100·0

To these quantities from 30 to 50 parts of broken glass or cullet are added; with about a two-thousandth part of manganese, and a three-thousandth part of arsenic. But manganese varies so extremely in its purity, and contains often so much oxyde of iron, the nothing can be predicated as to its quantity previously to trial.

M. Payen, an eminent manufacturing chemist in France, says that the composition of crystal does not deviate much from the following proportions :—

	Wood fire.	Coal fire
Silicious sand - - - - - -	3	3
Minium - - - - - - - -	2	2¼
Carbonate of potash - - - - -	1½	1⅔

I conceive that this glass contains too much lead and potash. Such a mixture will produce a dull metal, very attractive of moisture; defects to which the French crown-glass also is subject.

The flint-glass *leer* for annealing glass, is an arched gallery or large flue, about 36 feet long, 3 feet high, 4 wide; having its floor raised above 2 feet above the ground of the glass-house. The hot air and smoke of a fire-place at one end pass along this gallery, and are discharged by a chimney 8 or 10 feet short of the other end. On the floor of the vault, large iron trays are laid and hooked to each other in a series, which are drawn from the fire end towards the other by a chain, wound about a cylinder by a winch-handle projecting through the side. The flint-glass articles are placed in their hot state into the tray next the fire, which is moved onwards to a cooler station whenever it is filled, and an empty tray is set in its place. Thus, in the course of about 20 hours, the glass advances to the cool end thoroughly annealed.

Besides colorless transparent glass, which forms the most important part of this manufacture, various colored glasses are made to suit the taste of the public. The taste at Paris was lately for opaline crystal; which may be prepared by adding to the above composition (No. 2) phosphate of lime, or well burnt bone ash in fine powder, washed and dried. The article must be as uniform in thickness as possible, and speedily worked into shape, with a moderate heat. Oxyde of tin, *putty*, was formerly used for making opalescent glass, but the lustre of the body was always impaired by its means.

Crystal vessels have been made recently of which the inner surface is colorless, and all the external facets colored. Such works are easily executed. The end of the blowing-rod must be dipped first in the pot containing colorless glass, to form a bulb of a certain size, which being cooled a little is then dipped for an instant into the pot of colored glass. The two layers are associated without intermixture; and when the article is finished in its form, it is white within and colored without. Fluted lines, somewhat deeply cut, pass through the colored coat, and enter the colorless one; so that when they cross, their ends alone are colored.

For some time past, likewise, various crystal articles have been exhibited in the market with colored enamel-figures on their surface, or with white incrustations of a silvery lustre in their interior. The former are prepared by placing the enamel object in the brass mould, at the place where it is sought to be attached. The bulb of glass being put into the mould, and blown while very hot, the small plate of enamel gets cemented to the surface. For making the white argentine incrustations, small figures are prepared with an impalpable powder of dry porcelain paste, cemented into a solid by means of a little gypsum plaster. When these pieces are thoroughly dried, they are laid on the glass while it is red hot, and a large patch of very liquid glass is placed above it, so as to encase it and form one body with the whole. In this way the incrustation is completely enclosed; and the polished surface of the crystal, which scarcely touches it, gives a brilliant aspect, pleasing to the eye.

A uniform flint-glass, free from striæ, or *wreath*, is much in demand for the optician. It would appear that such an article was much more commonly made by the English manufacturers many years ago, than at present; and that in improving the brilliancy of crystal-glass they have injured its fitness for constructing optical lenses, which depends not so much on its whiteness and lustre as on the layers of different densities being parallel to each other. The oxyde of lead existing in certain parts of a potful of glass in greater proportion than in other parts, increases the density unequally in the same mass, so that the adjoining strata are often very different in this respect. Even a potful of pretty uniform glass, when it stands some time liquid, becomes eventually unequable by the subsidence of the denser portions; so that striæ and gelatinous appearances begin to manifest themselves, and the glass becomes of little value. Glass allowed to cool slowly in mass in the pot is particularly full of wreath; and if quickly refrigerated, that is, in two or three hours, it is apt to split into a multitude of minute splinters, of which no use can be made. For optical purposes, the glass must be taken out in its liquid state, being gathered on the end of the iron rod from the central portion of a recently skimmed pot, after the upper layers have been worked off in general articles.

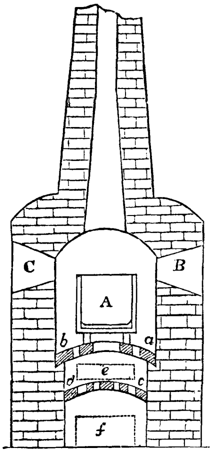
M. Guinand, of Brennets near Geneva, appears to have hit upon processes that furnished almost certainly pieces of flint-glass capable of forming good lenses of remarkable dimensions, even of 11 inches diameter; of adequate density and transparency, and nearly free from *striæ*. M. Cauchoix, the eminent French optician, says, that out of ten object glasses, 4 inches in diameter, made with M. Guinand's flint glass, eight or nine turned out very good, while out of an equal number of object glasses made of the flint glass of the English and French manufactories, only one, or two at most, were found serviceable. The means by which M. Guinand arrived at these results have not been published. He has lately died, and it is not known whether his son be in possession of his secret.

An achromatic object glass for telescopes and microscopes consists of at least two lenses; the one made with glass of lead, or flint-glass, and the other with crown-glass; the former possessing a power of dispersing the colored rays relatively to its mean refractive power, much greater than the latter; upon which principle the achromatism of the image is produced, by reuniting the different colored rays into one focus. Flint-glass to be fit for this delicate purpose must be perfectly homogeneous, or of uniform density throughout its substance, and free from wavy veins or wreaths; for every such inequality would occasion a corresponding inequality in the refraction and dispersion of the light; like what is perceived in looking through a thick and thin solution of gum-arabic imperfectly mixed. Three plans have been prescribed for obtaining homogeneous pieces of optical glass: 1. to lift a mass of it in large ladles, and let it cool in them; 2. to pour it out from the pots into moulds; 3. to allow it to cool in the pots, and afterwards to cut it off in horizontal strata. The last method, which is the most plausible, seldom affords pieces of uniform density, unless peculiar precautions have been adopted to settle the flint glass in uniform strata; because its materials are of such unequal density, the oxyde of lead having a specific gravity of 8, and silica of 2·7, that they are apt to stand at irregular heights in the pots.

One main cause of these inequalities lies in the construction of the furnace, whereby the bottom of the pot is usually much less heated than the upper part. In a plate glass furnace the temperature of the top of the pot has been found to be 130° Wedgew., while that of the bottom was only 110°, constituting a difference of no less than 2610° F. The necessary consequence is that the denser particles which subside to the bottom, during the fusion of the materials, and after the first extrication of the gases, must remain there, not being duly agitated by the expansive force of caloric, acting from below upwards.

The preparation of the best optical glass is now made a great mystery by one or two proficients. The following suggestions, deduced from a consideration of principles, may probably lead to some improvements, if judiciously applied. The great object is to counteract the tendency of the glass of lead to distribute itself into strata of different densities; which may be effected either by mechanical agitation or by applying the greatest heat to the bottom of the pot. But however homogeneous the glass may be thereby made, its subsequent separation into strata of different densities must be prevented by rapid cooling and solidification. As the deeper the pots, the greater is the chance of unequal specific gravity in their contents, it would be advisable to make them wider and shallower than those in use for making ordinary glass. The intermixture may be effected either by lading the glass out of one pot into another in the furnace, and back again, with copper ladles, or by stirring it up with a rouser, then allowing it to settle for a short time, till it becomes clear and free from air bubbles. The pot may now be removed from the furnace, in order to solidify its contents in their homogeneous state; after which the glass may be broken in pieces, and be perfected by subjecting it to a second fusion; or, what is easier and quicker, we may form suitable discs of glass without breaking down the potful, by lifting it out in flat copper ladles with iron shanks, and transferring the lumps after a little while into the annealing leer.

723



To render a potful of glass homogeneous by agitation, is a more difficult task, as an iron rod would discolor it, and a copper rod would be apt to melt. An iron rod sheathed in laminated platinum would answer well, but for its expense. A stone-ware tube supported within by a rod of iron, might also be employed for the purpose in careful hands; the stirring being repeated several times, till at last the glass is suffered to stiffen a little by decrease of temperature. It must then be allowed to settle and cool, after which the pot, being of small dimensions, may be drawn out of the fire.

2. The second method of producing the desired uniformity of mixture, consists in applying a greater heat to the bottom than to the upper part of the melting pot. *Fig.* 723 represents in section a furnace contrived to effect this object. It is cylindrical, and of a diameter no greater than to allow the flames to play round the pot, containing from three to four cwts. of vitreous materials. A is the pot, resting upon the arched grid *b a*, built of fire-bricks, whose apertures are wide enough to let the flames rise freely, and strike the bottom and sides of the vessel. From 1½ to 2 feet under that arch, the fuel grate *c d* is placed. B C are the two working openings for introducing the materials, and inspecting the progress of the fusion; they must be closed with fire-tiles and luted with fire-clay at the beginning of the process. At the back of the furnace, opposite the mouth

of the fire-place there is a door-way, which is bricked up, except upon occasion of putting in and taking out the pot. The draught is regulated by means of a slide-plate upon the mouth of the ash-pit *f*. The pot being heated to the proper pitch, some purified pearlash, mixed with fully twice its weight of colorless quartz sand, is to be thrown into it, and after the complete fusion of this mixture, the remaining part of the sand along with the oxyde of lead (fine litharge) is to be strown upon the surface. These silicious particles in their descent serve to extricate the air from the mass. Whenever the whole is fused, the heat must be strongly urged, to ensure a complete uniformity of combination by the internal motions of the particles. As soon as the glass has been found, by making test vials, to be perfectly fine, the fire must be withdrawn, the two working holes must be opened, as well as the mouths of the fire-place and ash-pit, to admit free ingress to cooling currents of air, so as to congeal the liquid mass as quickly as possible; a condition essential to the uniformity of the glass. It may be worth while to stir it a little with the pottery rod at the commencement of the cooling process. The solidified glass may be afterwards detached by a hammer in conchoidal discs, which, after chipping off their edges, are to be placed in proper porcelain or stone-ware dishes, and exposed to a softening heat, in order to give them a lenticular shape. Great care must be taken that the heat thus applied by the muffle furnace be very equable, for otherwise wreaths might be very readily reproduced in the discs. A small oven, upon the plan of a baker's, is best fitted for this purpose, which being heated to dull redness, and then extinguished, is ready to soften and afterwards anneal the conchoidal pieces.

Guinand's dense optical flint glass, of specific gravity 3·616, consists, by analysis, of oxyde of lead, 43·05; silica, 44·3; and potash, 11·75; but requires for its formation the following ingredients: 100 pounds of ground quartz; 100 pounds of fine red lead; 35 pounds of purified potash; and from 2 to 4 pounds of saltpetre. As this species of glass is injured by an excess of potash, it should be compounded with rather a defect of it, and melted by a proportionably higher or longer heat. A good optical glass has been made in Germany with 7 parts of pure red lead, 3 parts of finely ground quartz, and 2 parts of calcined borax.

5. *Plate glass.*

This, like English crown-glass, has a soda flux; whereas flint-glass requires potash, and is never of good quality when made with soda. We shall distribute our account of this manufacture under two heads.

1. The different furnaces and principal machines, without whose knowledge it would be impossible to understand the several processes of a plate-glass factory.

2. The materials which enter into the composition of this kind of glass, and the series of operations which they undergo; devoting our chief attention to the changes and improvements which long experience, enlightened by modern chemistry, has introduced into the great manufactory of Saint-Gobin, in France, under the direction of M. Tassaert. It may however be remarked, that the English plate-glass manufacture derives peculiar advantages from the excellence of its grinding and polishing machinery.

The clay for making the bricks and pots should be free from lime and iron, and very refractory. It is mixed with the powder of old pots passed through a silk sieve. If the clay be very plastic it will bear its own weight of the powder, but if shorter in quality, it will take only three fifths. But before mingling it with the cement of old pots, it must be dried, bruised, then picked, ground, and finally elutriated by agitation with water, decantation through a hair sieve, and subsidence. The clay fluid after passing the sieve is called *slip* (coulis).

The furnace is built of dry bricks, cemented with slip, and has at each of its four angles a peculiar annealing arch, which communicates with the furnace interiorly, and thence derives sufficient heat to effect in part, if not wholly, the annealing of the pots, which are always deposited there a long time before they are used. Three of these arches, exclusively appropriated to this purpose, are called pot-arches. The fourth is called the *arch of the materials*, because it serves for drying them before they are founded. Each arch has, moreover, a principal opening called the throat, another called *bonnard*, by the French workmen, through which fire may be kindled in the arch itself, when it was thought to be necessary for the annealing of the pots; a practice now abandoned. The duration of a furnace is commonly a year, or at most 14 months; that of the arches is 30 years or upwards, as they are not exposed to so strong a heat.

In the manufacture of plate-glass two sorts of crucibles are employed, called the pots and the basins (*cuvettes*). The first serve for containing the materials to be founded, and for keeping them a long time in the melted state. The *cuvettes* receive the melted glass after it is refined, and decant it out on the table to be rolled into a plate. Three pots hold liquid glass for six small basins, or for three large ones, the latter being employed for making mirrors of great dimensions, that is, 100 inches long and upwards. Furnaces have been lately constructed with 6 pots, and 12 cuvettes, 8 of which are small, and 4 large; and cuvettes of three sizes are made, called *small, middling,* and *large.* The small are perfect cubes, the middling and the large ones are oblong parallelopipeds. Towards the middle of their height, a notch or groove, two or three inches broad, and an inch deep, is left, called the girdle of the cuvette, by which part they are grasped with the tongs, or rather are clamped in the iron frame. This frame goes round the four sides of the small cuvettes, and may be placed indifferently upon all their sides; in the other cuvettes, the girdle extends only over the two large sides, because they cannot be turned up. See *m* r, *fig.* 724, p. 918.

The pot is an inverted truncated cone, like a crown glass pot. It is about 30 inches high, and from 30 to 32 inches wide, including its thickness. There are only a few inches of difference between the diameter of the top and that of the bottom. The bottom is 3 inches thick, and the body turns gradually thinner till it is an inch at the mouth of the pot.

The large building or factory, of which the melting furnace occupies the middle space, is called the *halle* in French. At Ravenhead in Lancashire it is called the foundry, and is of magnificent dimensions, being probably the largest apartment under one roof in Great Britain, since its length is 339 feet, and its breadth 155. The famous *halle* of St. Gobin is 174 feet by 120. Along the two side walls of the *halle,* which are solidly constructed of hewn stone, there are openings like those of common ovens. These ovens, destined for the annealing of the newly cast plates, bear the name of *carquaises.* Their soles are raised two feet and a half above the level of the ground, in order to bring them into the same horizontal plane with the casting tables. Their length, amounting sometimes to 30 feet, and their breadth to 20, are required in order to accommodate 6, 8, or even 10 plates of glass, alongside of each other. The front aperture is called the throat, and the back door the little throat (*gueulette*). The carquaise is heated by means of a fire-place of a square form called a *tisar,* which extends along its side.

The founding or melting furnace is a square brick building laid on solid foundations, being from 8 to 10 feet in each of its fronts, and rising inside into a vault or crown about 10 feet high. At each angle of this square, a small oven or arch is constructed, likewise vaulted within, and communicating with the melting furnace by square flues, called *lunettes,* through which it receives a powerful heat, though much inferior to that round the pots. The arches are so distributed as that two of the exterior sides of the furnace stand wholly free, while the two other sides, on which the arches encroach, offer a free space of only three feet. In this interjacent space, two principal openings of the furnace, of equal size in each side, are left in the building. These are called tunnels. They are destined for the introduction of the pots and the fuel.

On looking through the tunnels into the inside of the furnace, we perceive to the right hand and the left, along the two *free* sides, two low platforms or *sieges,* at least 30 inches in height and breadth. See *figs.* 715, 717.

These *sieges* (seats) being intended to support the pots and the cuvettes filled with heavy materials, are terminated by a slope, which ensures the solidity of the fire-clay mound. The slopes of the two sieges extend towards the middle of the furnace so near as to leave a space of only from 6 to 10 inches between them for the hearth. The end of this is perforated with a hole sufficiently large to give passage to the liquid glass of a broken pot, while the rest is preserved by lading it from the mouth into the adjoining cuvette.

In the two large parallel sides of the furnace, other apertures are left much smaller than the tunnels, which are called *ouvreaux* (peep holes). The lower ones, or the *ouvreaux en bas,* called *cuvette* openings, because, being allotted to the admission of these vessels, they are exactly on a level with the surface of the *sieges,* and with the floor of the *halle.* Plates of cast-iron form the thresholds of these openings, and facilitate the ingress and egress of the cuvettes. The apertures are arched at top, with hewn stone like the tunnels, and are 18 inches wide when the cuvettes are 16 inches broad.

The upper and smaller apertures, or the higher *ouvreaux* called the *lading* holes, because they serve for transvasing the liquid glass, are three in number, and are placed 31 or 32 inches above the surface of the *sieges.* As the pots are only 30 inches high, it becomes easy to work through these openings either in the pots or the *cuvettes.* The pots stand opposite to the two pillars which separate the openings, so that a space is left between them for one or more *cuvettes* according to the size of the latter. It is obvious that if the tunnels and *ouvreaux* were left open, the furnace would not draw or take the requisite founding heat. Hence the openings are shut by means of fire-tiles. These are put in their places, and removed by means of two holes left in them, in correspondence with the two prongs of a large iron fork supported by an axle and two iron wheels, and terminated by two handles which the workmen lay hold of when they wish to move the tile.

The closing of the tunnel is more complex. When it is shut or ready for the firing the aperture appears built up with bricks and mortar from the top of the arch to the middle of the tunnel. The remainder of the door-way is closed; 1. on the two sides down to the bottom, by a small upright wall, likewise of bricks, and 8 inches broad, called walls of the *glaye;* 2. by an assemblage of pieces called pieces of the *glaye,* because the whole of the closure of the tunnel bears the name of *glaye.* The upper hole, 4 inches square, is called the *tisar,* through which billets of wood are tossed into the fire. Fuel is also introduced into the posterior openings. The fire is always kept up on the hearth of the tunnel, which is, on this account, 4 inches higher than the furnace-hearth, in order that the glass which may accidentally fall down on it, and which does not flow off by the bottom hole, may not impede the combustion. Should a body of glass, however, at any time obstruct the grate, it must be removed with rakes, by opening the tunnel and dismounting the fire-tile stoppers of the *glaye.*

Formerly wood fuel alone was employed for heating the melting-furnaces of the mirror-plate manufactory of Saint Gobin; but within these few years, the Director of the works makes use with nearly equal advantage of pit-coal. In the same establishment, two melting furnaces may be seen, one of which is fixed with wood, and the other with coals, without any difference being perceptible in the quality of the glass furnished by either. It is not true, as has been stated, that the introduction of pit-coal has made it necessary to work with covered pots in order to avoid the discoloration of the materials, or that more alkali was required to compensate for the diminished heat in the covered pots. They are not now covered when pit-coal is used, and the same success is obtained as heretofore by leaving the materials two or three hours longer in the pots and the cuvettes. The construction of the furnaces in which coal is burned, is the same as that with wood, with slight modifications. Instead of the close bottomed hearth of the wood furnace, there is an iron grate in the coal-hearth through which the air enters, and the waste ashes descend.

When billets of wood were used as fuel, they were well dried beforehand, by being placed a few days on a frame-work of wood called the wheel, placed two feet above the furnace and its arches, and supported on four pillars at some distance from the angles of the building.

Composition of plate-glass.—This is not made now, as formerly, by random trials. The progress of chemistry, the discovery of a good process for the manufacture of soda from sea salt, which furnishes a pure alkali of uniform power, and the certain methods of ascertaining its purity, have rendered this department of glass-making almost entirely new, in France. At Saint Gobin no alkali is employed at present except artificial crystals of soda, prepared at the manufactory of Chauny, subsidiary to that establishment. Leaden chambers are also erected there for the production of sulphuric acid from sulphur. The first crop of soda crystals is reserved for the plate-glass manufacture, the other crystals and the mother-water salts are sold to the makers of inferior glass.

At the mirror-plate works of Ravenhead, near St. Helen's in Lancashire, soda crystals, from the decomposition of the sulphate of soda by chalk and coal, have been also tried, but without equal success as at Saint Gobin; the failure being unquestionably due to the impurity of the alkali. Hence, in the English establishment the soda is obtained by treating sea-salt with pearl-ash, whence carbonate of soda and muriate of potash result. The latter salt is crystallized out of the mingled solution, by evaporation at a moderate heat, for the carbonate of soda does not readily crystallize till the temperature of the solution falls below 60° Fahr. When the muriate of potash is thus removed, the alkaline carbonate is evaporated to dryness.

Long experience at Saint Gobin has proved that one part of dry carbonate of soda is adequate to vitrify perfectly three parts of fine silicious sand, as that of the mound of Aumont near Senlis, of Alum Bay in the Isle of Wight, or of Lynn in Norfolk. It is also known that the degree of heat has a great influence upon the vitrification, and that increase of temperature will compensate for a certain deficiency of alkali; for it is certain that a very strong fire always dissipates a good deal of the soda, and yet the glass is not less beautiful. The most perfect mirror-plate has constantly afforded to M. Vauquelin in analysis, a portion of soda inferior to what had been employed in its formation. Hence, it has become the practice to add for every 100 parts of cullet or broken plate that is mixed with the glass composition, one part of alkali, to make up for the loss that the old glass must have experienced.

To the above mentioned proportions of sand and alkali independently of the cullet which may be used, dry slaked lime carefully sifted is to be added to the amount of one seventh of the sand; or the proportion will be, sand 7 cwts.; quicklime 1 cwt.; dry carbonate of soda 2 cwts. and 37 lbs.; besides cullet. The lime improves the quality of the glass; rendering it less brittle and less liable to change. The preceding quantities of materials, suitably blended, have been uniformly found to afford most advantageous results. The practice formerly was to dry that mixture as soon as it was made, in the arch for the materials, but it has been ascertained that this step may be dispensed with, and the small portion of humidity present is dissipated almost instantly after they are thrown into the furnace. The coat of glaze previously applied to the inside of the pot, prevents the moisture from doing them any harm. For this reason, when the demand for glass at Saint-Gobin is very great, the materials are neither fritted nor even dried, but shovelled directly into the pot; this is called founding *raw*. Six workmen are employed in shovelling-in the materials either fritted or otherwise, for the sake of expedition, and to prevent the furnace getting cooled. One third of the mixture is introduced at first; whenever this is melted, the second third is thrown in, and then the last. These three stages are called the first, second, and third fusion or founding.

According to the ancient practice, the founding and refining were both executed in the pots, and it was not till the glass was refined, that it was laded into the cuvettes, where it remained only 3 hours, the time necessary for the disengagement of the air bubbles introduced by the transvasion, and for giving the *metal* the proper consistence for casting. At present, the period requisite for founding and refining, is equally divided between the pots and the *cuvettes*. The materials are left 16 hours in the pots, and as many in the *cuvettes;* so that in 32 hours the glass is ready to be cast. During the last two or three hours, the fireman or *tiseur* ceases to add fuel; all the openings are shut, and the glass is allowed to assume the requisite fluidity; an operation called *stopping* the glass, or *performing the ceremony.*

The transfer of the glass into the *cuvettes*, is called *lading*, (*tréjetage*). Before this is done, the cuvettes are cleared out, that is, the glass remaining on their bottom is removed, and the ashes of the firing. They are lifted red hot out of the furnace by the method presently to be described, and placed on an iron plate, near a tub filled with water. The workmen, by means of iron paddles 6 feet long, flattened at one end and hammered to an edge, scoop out the fluid glass expeditiously, and throw it into water; the *cuvettes* are now returned to the furnace, and a few minutes afterwards the lading begins.

In this operation, ladles of wrought iron are employed, furnished with long handles, which are plunged into the pots through the upper openings or lading holes, and immediately transfer their charge of glass into the buckets. Each workman dips his ladle only three times, and empties its contents into the cuvette. By these three immersions (whence the term *tréjeter* is derived), the large iron spoon is heated so much that when plunged into a tub full of water, it makes a noise like the roaring of a lion, which may be heard to a very great distance.

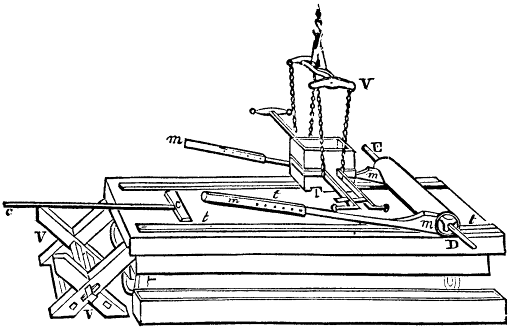
The founding, refining, and *ceremony*, being finished, they next try whether the glass be ready for casting. With this view, the end of a rod is dipped into the bucket, which is called *drawing the glass;* the portion taken up being allowed to run off, naturally assumes a pear-shape, from the appearance of which, they can judge if the consistence be proper, and if any air bubbles remain. If all be right, the *cuvettes* are taken out of the furnace, and conveyed to the part of the *halle* where their contents are to be poured out. This process requires peculiar instruments and manipulations.

Casting.—While the glass is refining, that is, coming to its highest point of perfection, preparation is made for the most important process, the casting of the plate, whose success crowns all the preliminary labors and cares. The oven or *carquaise* destined to receive and anneal the plate is now heated by its small fire or *tisar*, to such a pitch that its sole may have the same temperature as that of the plates, being nearly red-hot at the moment of their being introduced. An unequal degree of heat in the *carquaise* would cause breakage of the glass. The casting table is then rolled towards the front door or throat, by means of levers, and its surface is brought exactly to the level of the sole of the oven.

The table T, *fig.* 724, is a mass of bronze, or now preferably cast iron, about 10 feet long, 5 feet broad, and from 6 to 7 inches thick, supported by a frame of carpentry, which rests on three cast iron wheels. At the end of the table opposite to that next to the front of the oven, is a very strong frame of timber-work, called the puppet or standard, upon which the bronze roller which spreads the glass is laid, before and after the casting. This is 5 feet long by 1 foot in diameter; it is thick in the metal but hollow in the axis. The same roller can serve only for two plates at one casting, when another is put in its place, and the first is laid aside to cool; for otherwise the hot roller would at a third casting make the plate expand unequally, and cause it to crack. When the rollers are not in action, they are laid aside in strong wooden trestles, like those employed by sawyers. On the two sides of the table in the line of its length, are two parallel bars of bronze, *t, t*, destined to support the roller during its passage from end to end; the thickness of these bars determines that of the plate. The table being thus arranged, a crane is had recourse to for lifting the cuvette, and keeping it suspended, till it be emptied upon the table. This raising and suspension are effected by means of an iron gib, furnished with pulleys, held horizontally, and which turns with them.

The tongs T, *fig.* 724, are made of four iron bars, bent into a square frame in their middle, for embracing the bucket. Four chains proceeding from the corners of the frame V are united at their other ends into a ring which fits into the hook of the crane.

724



Things being thus arranged, all the workmen of the foundry co-operate in the manipulations of the casting. Two of them fetch, and place quickly in front of one of the lower openings, the small cuvette-carriage, which bears a forked bar of iron, having two prongs corresponding to the two holes left in the fire-tile door. This fork, mounted on the axle of two cast-iron wheels, extends at its other end into two branches terminated by handles, by which the workmen move the fork, lift out the tile stopper, and set it down against the outer wall of the furnace.

The instant these men retire, two others push forward into the opening the extremity of the tongs-carriage, so as to seize the bucket by the girdle, or rather to clamp it. At the same time, a third workman is busy with an iron pinch or long chisel, detaching the bucket from its seat, to which it often adheres by some spilt glass; whenever it is free, he withdraws it from the furnace. Two powerful branches of iron united by a bolt, like two scissor blades, which open, come together, and join by a quadrant near the other end, form the tongs-carriage, which is mounted upon two wheels like a truck.

The same description will apply almost wholly to the iron-plate carriage, on which the bucket is laid the moment it is taken out of the furnace; the only difference in its construction is, that on the bent iron bars which form the tail or lower steps of this carriage (in place of the tongs) is permanently fastened an iron plate, on which the bucket is placed and carried for the casting.

Whenever the *cuvette* is set upon its carriage, it must be rapidly wheeled to its station near the crane. The tongs T above described are now applied to the girdle, and are then hooked upon the crane by the suspension chains. In this position the bucket is skimmed by means of a copper tool called a sabre, because it has nearly the shape of that weapon. Every portion of the matter removed by the sabre is thrown into a copper ladle (*poche de gamin*), which is emptied from time to time into a cistern of water. After being skimmed, the bucket is lifted up, and brushed very clean on its sides and bottom; then by the double handles of the suspension-tongs it is swung round to the table, where it is seized by the workmen appointed to turn it over; the roller having been previously laid on its ruler-bars, near the end of the table which is in contact with the annealing oven. The *cuvette*-men begin to pour out towards the right extremity E of the roller, and terminate when it has arrived at the left extremity D. While preparing to do so, and at the instant of casting, two men place within the ruler-bar on each side, that is, between the bar and the liquid glass, two iron instruments called *hands*, *m*, *m*, *m*, *m*, which prevent the glass from spreading beyond the rulers, while another draws along the table the wiping bar *c*, *c*, wrapped in linen, to remove dust, or any small objects which may interpose between the table and the liquid glass.

Whenever the melted glass is poured out, two men spread it over the table, guiding the roller slowly and steadily along, beyond the limits of the glass, and then run it smartly into the wooden standard prepared for its reception, in place of the trestles V, V.

The empty bucket, while still red-hot, is hung again upon the crane, set on its plate-iron carriage, freed from its tongs, and replaced in the furnace, to be speedily cleared out anew, and charged with fresh fluid from the pots. If while the roller glides along, the two workmen who stand by with picking tools, perceive *tears* in the matter in advance of the roller, and can dexterously snatch them out, they are suitably rewarded, according to the spot where the blemish lay, whether in the centre, where it would have proved most detrimental, or near the edge. These tears proceed usually from

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small portions of semi-vitrified matter which fall from the vault of the furnace, and from their density occupy the bottom of the *cuvettes.*

While the plate is still red-hot and ductile, about 2 inches of its end opposite to the *carquaise* door is turned up with a tool; this portion is called the *head of the mirror;* against the outside of this head, the shovel, in the shape of a rake without teeth, is applied, with which the plate is eventually pushed into the oven, while two other workmen press upon the upper part of the head with a wooden pole, eight feet long, to preserve the plate in its horizontal position, and prevent its being warped. The plate is now left for a few moments near the throat of the *carquaise,* to give it solidity; after which it is pushed farther in by means of a very long iron tool, whose extremity is forked like the letter y, and hence bears that name; and is thereby arranged in the most suitable spot for allowing other plates to be introduced.

However numerous the manipulations executed from the moment of withdrawing the *cuvette* from the furnace, till the cast-plate is pushed into the annealing oven, I have seen them all performed in less than five minutes; such silence, order, regularity, and despatch prevail in the establishment of Saint-Gobin.

When all the plates of the same casting have been placed in the *carquaise,* it is sealed up, that is to say, all its orifices are closed with sheets of iron, surrounded and made tight with plastic loam. With this precaution, the cooling goes on slowly and equably in every part, for no cooling-current can have access to the interior of the oven.

After they are perfectly cooled, the plates are carefully withdrawn one after another, keeping them all the while in a horizontal position, till they are entirely out of the *carquaise.* As soon as each plate is taken out, one set of workmen lower quickly and steadily the edge which they hold, while another set raise the opposite edge, till the glass be placed upright on two cushions stuffed with straw, and covered with canvass. In this vertical position they pass through, beneath the lower edge of the plate, three girths or straps each four feet long, thickened with leather in their middle, and ending in wooden handles; so that one embraces the middle of the plate, and the other two, the ends. The workmen, six in number, now seize the handles of the straps, lift up the glass closely to their bodies, and convey it with a regular step to the warehouse. Here the head of the plate is first cut off with a diamond square, and then the whole is attentively examined, in reference to its defects and imperfections, to determine the sections which must be made of it, and the eventual size of the pieces. The pairings and small cuttings detached are set aside, in order to be ground and mixed with the raw materials of another glass-pot.

The apartment in which the roughing-down and smoothing of the plates is performed, is furnished with a considerable number of stone tables truly hewn and placed apart like billiard tables, in a horizontal position, about 2 feet above the ground. They are rectangular, and of different sizes proportional to the dimensions of the plates, which they ought always to exceed a little. These tables are supported either on stone pillars or wooden frames, and are surrounded with a wooden board whose upper edge stands somewhat below their level, and leaves in the space between it and the stone all round an interval of 3 or 4 inches, of which we shall presently see the use.

A cast plate, unless formed on a table quite new, has always one of its faces, the one next the table, rougher than the other; and with this face the roughing-down begins. With this view, the smoother face is cemented on the stone table with Paris-plaster. But often, instead of one plate, several are cemented alongside of each other, those of the same thickness being carefully selected. They then take one or more crude plates of about one third or one fourth the surface of the plate fixed to the table, and fix it on them with liquid gypsum to the large base of a quadrangular truncated pyramid of stone, of a weight proportioned to its extent, or about a pound to the square inch. This pyramidal muller, if small sized, bears at each of its angles of the upper face a peg or ball, which the grinders lay hold of in working it; but when of greater dimension, there is adapted to it horizontally a wheel of slight construction, 8 or 10 feet in diameter, whose circumference is made of wood rounded so as to be seized with the hand. The upper plate is now rubbed over the lower ones, with moistened sand applied between.

This operation is however performed by machinery. The under plate being fixed or imbedded in stucco, on a solid table, the upper one likewise imbedded by the same cement in a cast-iron frame, has a motion of circumrotation given to it closely resembling that communicated by the human hand and arm, moist sand being supplied between them. While an eccentric mechanism imparts this double rotatory movement to the upper plate round its own centre, and of that centre round a point in the lower plate, this plate, placed on a moveable platform, changes its position by a slow horizontal motion, both in the direction of its length and its breadth. By this ingenious contrivance, which pervades the whole of the grinding and polishing machinery, a remarkable regularity of friction and truth of surface is produced. When the plates are sufficiently worked on one face, they are reversed in the frames, and worked together or the other. The Paris plaster is usually colored red, in order to show any defects in the glass.

The smoothing of the plates is effected on the same principles by the use of moist emery washed to successive degrees of fineness, for the successive stages of the operation; and the polishing process is performed by rubbers of hat-felt and a thin paste of colcothar and water. The colcothar, called also crocus, is red oxyde of iron prepared by the ignition of copperas, with grinding and elutriation of the residuum.

The last part or the polishing process is performed by hand. This is managed by females, who slide one plate over another, while a little moistened putty of tin finely levigated is thrown between.

Large mirror-plates are now the indispensable ornaments of every large and sumptuous apartment; they diffuse lustre and gayety round them, by reflecting the rays of light in a thousand lines, and by multiplying indefinitely the images of objects placed between opposite parallel planes.

The *silvering* of *plane* mirrors consists in applying a layer of tin-foil alloyed with mercury to their posterior surface. The workshop for executing this operation is provided with a great many smooth tables of fine freestone or marble, truly levelled, having round their contour a rising ledge, within which there is a gutter or groove which terminates by a slight slope in a spout at one of the corners. These tables rest upon an axis of wood or iron which runs along the middle of their length; so that they may be inclined easily into an angle with the horizon of 12 or 13 degrees, by means of a hand-screw fixed below. They are also furnished with brushes, with glass rules, with rolls of woollen stuff, several pieces of flannel, and a great many weights of stone or cast-iron.

The glass-tinner, standing towards one angle of his table, sweeps and wipes its surface with the greatest care, along the whole surface to be occupied by the mirror-plate; then taking a sheet of tin-foil adapted to his purpose, he spreads it on the table, and applies it closely with a brush, which removes any folds or wrinkles. The table being horizontal, he pours over the tin a small quantity of quicksilver, and spreads it with a roll of woollen stuff; so that the tin-foil is penetrated and apparently dissolved by the mercury. Placing now two rules, to the right and to the left, on the borders of the sheet, he pours on the middle a quantity of mercury sufficient to form everywhere a layer about the thickness of a crown piece; then removing with a linen rag the oxyde or other impurities, he applies to it the edge of a sheet of paper, and advances it about half an inch. Meanwhile another workman is occupied in drying very nicely the surface of the glass that is to be silvered, and then hands it to the master workman, who, laying it flat, places its anterior edge first on the table, and then on the slip of paper; now pushing the glass forwards, he takes care to slide it along so that neither air nor any coat of oxyde on the mercury can remain beneath the plate. When this has reached its position, he fixes it there by a weight applied on its side, and gives the table a gentle slope, to run off all the loose quicksilver by the gutter and spout. At the end of five minutes he covers the mirror with a piece of flannel, and loads it with a great many weights which are left upon it for twenty-four hours, under a gradually increased inclination of the table. By this time the plate is ready to be taken off the marble table, and laid on a wooden one sloped like a reading desk, with its under edge resting on the ground, while the upper is raised successively to different elevations by means of a cord passing over a pulley in the ceiling of the room. Thus the mirror has its slope graduated from day to day, till it finally arrives at a vertical position. About a month is required for draining out the superfluous mercury from large mirrors; and from 18 to 20 days from those of moderate size. The sheets of tin-foil being always somewhat larger than the glass plate, their edges must be paired smooth off, before the plate is lifted off the marble table.

Process for silvering concave mirrors.—Having prepared some very fine Paris plaster by passing it through a silk sieve, and some a little coarser passed through hair-cloth, the first is to be made into a creamy liquor with water, and after smearing the concave surface of the glass with a film of olive oil, the fine plaster is to be poured into it, and spread by turning about, till a layer of plaster be formed about a tenth of an inch thick. The second or coarse plaster, being now made into a thin paste, poured over the first, and moved about, readily incorporates with it, in its imperfectly hardened state. Thus an exact mould is obtained of the concave surface of the glass, which lies about three quarters of an inch thick upon it, but is not allowed to rise above its outer edge.

The mould, being perfectly dried, must be marked with a point of coincidence on the glass, in order to permit of its being exactly replaced in the same position, after it has been lifted out. The mould is now removed, and a round sheet of tin-foil is applied to it, so large that an inch of its edge may project beyond the plaster all round; this border being necessary for fixing the tin to the contour of the mould by pellets of white wax softened a little with some Venice turpentine. Before fixing the tin-foil, however, it must be properly spread over the mould, so as to remove every wrinkle; which the pliancy of the foil easily admits of, by uniform and well-directed pressure with the fingers.

The glass being placed in the hollow bed of a tight sack filled with fine sand, set in a well-jointed box, capable of retaining quicksilver, its concave surface must be dusted with sifted wood-ashes, or Spanish white contained in a small cotton bag, and then well wiped with clean linen rags, to free it from all adhering impurity, and particularly the moisture of the breath. The concavity must be now filled with quicksilver to the very lip, and the mould, being dipped a little way into it, is withdrawn, and the adhering mercury is spread over the tin with a soft flannel roll, so as to amalgamate and brighten its whole surface, taking every precaution against breathing on it. Whenever this brightening seems complete, the mould is to be immersed, not vertically, but one edge at first, and thus obliquely downwards till the centres coincide; the mercury meanwhile being slowly displaced, and the mark on the mould being brought finally into coincidence with the mark on the glass. The mould is now left to operate by its own weight, in expelling the superfluous mercury, which runs out upon the sand-bag and thence into a groove in the bottom of the box, whence it overflows by a spout into a leather bag of reception. After half an hour's repose, the whole is cautiously inverted, to drain off the quicksilver more completely. For this purpose, a box like the first is provided with a central support rising an inch above its edges; the upper surface of the support being nearly equal in diameter to that of the mould. Two workmen are required to execute the following operation. Each steadies the mould with the one hand, and raises the box with the other, taking care not to let the mould be deranged, which they rest on the (convex) support of the second box. Before inverting the first apparatus, however, the reception bag must be removed, for fear of spilling its mercury. The redundant quicksilver now drains off; and if the weight of the sandbag is not thought sufficient, supplementary weights are added at pleasure. The whole is left in this position for two or three days. Before separating the mirror from its mould, the border of tinfoil, fixed to it with wax, must be pared off with a knife. Then the weight and sandbag being removed, the glass is lifted up with its interior coating of tin-amalgam.

For silvering a convex surface.—A concave plaster mould is made on the convex glass, and their points of coincidence are defined by marks. This mould is to be lined with tinfoil, with the precautions above described; and the tin surface being first brightened with a little mercury, the mould is then filled with the liquid metal. The glass is to be well cleaned, and immersed in the quicksilver bath, which will expel the greater part of the metal. A sandbag is now to be laid on the glass, and the whole is to be inverted as in the former case on a support; when weights are to be applied to the mould, and the mercury is left to drain off for several days.

If the glass be of large dimensions, 30 or 40 inches, for example, another method is adopted. A circular frame or hollow ring of wood or iron is prepared, of twice the diameter of the mirror, supported on three feet. A circular piece of new linen cloth of close texture is cut out, of equal diameter to the ring, which is hemmed stoutly at the border, and furnished round the edge with a row of small holes, for lacing the cloth to the ring, so as to leave no folds in it, but without bracing it so tightly as to deprive it of the elasticity necessary for making it into a mould. This apparatus being set horizontally, a leaf of tinfoil is spread over it, of sufficient size to cover the surface of the glass; the tin is first brightened with mercury, and then as much of the liquid metal is poured on as a plane mirror requires. The convex glass, well cleaned, is now set down on the cloth, and its own weight, joined to some additional weights, gradually presses down the cloth, and causes it to assume the form of the glass which thus comes into close contact with the tin submersed under the quicksilver. The redundant quicksilver is afterwards drained off by inversion, as in common cases.

The following recipe has been given for silvering the inside of glass globes. Melt in an iron ladle or a crucible, equal parts of tin and lead, adding to the fused alloy one part of bruised bismuth. Stir the mixture well, and pour into it as it cools, two parts of dry mercury; agitating anew and skimming off the drossy film from the surface of the amalgam. The inside of the glass globe, being freed from all adhering dust and humidity, is to be gently heated, while a little of the semi-fluid amalgam is introduced. The liquidity being increased by the slight degree of heat, the metallic coating is applied to all the points of the glass, by turning round the globe in every direction, but so slowly as to favor the adhesion of the alloy. This silvering is not so substantial as that of plane mirrors: but the form of the vessel, whether a globe, an ovoid, or a cylinder, conceals or palliates the defects by counter reflection from the opposite surfaces.

Colored Glasses and Artificial Gems.—The general vitreous body preferred by Fontanieu in his treatise on this subject, which he calls the Mayence base, is prepared in the following manner. Eight ounces of pure rock-crystal or flint in powder, mixed with 24 ounces of salt of tartar, are baked and left to cool. This is afterwards poured into a basin of hot water, and treated with dilute nitric acid till it ceases to effervesce, when the frit is to be washed till the water comes off tasteless. The frit is now dried and mixed with 12 ounces of fine white lead, and the mixture is to be levigated and elutriated with a little distilled water. An ounce of calcined borax is to be added to about 12 ounces of the preceding mixture in a dry state, the whole rubbed together in a porcelain mortar, then melted in a clean crucible, and poured out into cold water. This vitreous matter must be dried, and melted a second and a third time, always in a new crucible, and after each melting poured into cold water as at first, taking care to separate the lead that may be revived. To the last glass ground to powder, five drachms of nitre are to be added, and the mixture being melted for the last time, a mass of crystal will be found in the crucible with a beautiful lustre. The diamond is well imitated by this Mayence base. Another very fine white crystal may be obtained, according to M. Fontanieu, from eight ounces of white lead, two ounces of powdered borax, half a grain of manganese, and three ounces of rock-crystal, treated as above.

The colors of artificial gems are obtained from metallic oxydes. The *oriental topaz* is prepared by adding oxyde of antimony to the base; the amethyst from manganese, with a little purple precipitate of Cassius; the beryl from antimony and a very little cobalt; yellow artificial diamond and opal from horn-silver (chloride of silver); blue stone from cobalt. See PASTES and PIGMENTS VITRIFIABLE.

The following are recipes for making the different kinds of glass.

1. *Bottle glass.*—11 pounds of dry glauber salts; 12 pounds of soaper salts; a half bushel of waste soap ashes; 56 pounds of sand; 22 pounds of glass skimmings; 1 cwt. of green broken glass; 25 pounds of basalt. This mixture affords a dark green glass.

2. Yellow or white sand, 100 parts; kelp, 30 to 40; lixiviated wood ashes, from 160 to 170 parts; fresh wood ashes, 30 to 40 parts; potter's clay, 80 to 100 parts; cullet or broken glass, 100. If basalt be used, the proportion of kelp may be diminished.

In two bottle-glass houses in the neighborhood of Valenciennes, an unknown ingredient, sold by a Belgian, was employed, which he called *spar*. This was discovered by chemical analysis to be sulphate of baryta. The glass-makers observed that the bottles which contained some of this substance were denser, more homogeneous, more fusible, and worked more kindly, than those formed of the common materials. When one prime equivalent of the silicate of baryta = 123, is mixed with three primes of the silicate of soda = (3 × 77·6) 232·8, and exposed in a proper furnace, vitrification readily ensues, and the glass may be worked a little under a cherry red heat, with as much ease as a glass of lead, and has nearly the same lustre. Since the ordinary run of glass-makers are not familiar with atomic proportions, they should have recourse to a scientific chemist, to guide them in using such a proportion of sulphate of baryta as may suit their other vitreous ingredients; for an excess or defect of any of them will injure the quality of the glass.

3. *Green window glass, or broad glass.*—11 pounds of dry glauber salts; 10 pounds of soaper salts; half a bushel of lixiviated soap waste; 50 pounds of sand; 22 pounds of glass pot skimmings; 1 cwt. of broken green glass.

4. *Crown glass.*—300 parts of fine sand; 200 of good soda ash; 33 of lime; from 250 to 300 of broken glass; 60 of white sand; 30 of purified potash; 15 of saltpetre (1 of borax); ½ of arsenious acid.

5. *Nearly white table glass.*—20 pounds of potashes; 11 pounds of dry glauber salts; 16 of soaper salt; 55 of sand; 140 of cullet of the same kind. Another.—100 of sand; 235 of kelp; 60 of wood ashes; 1⅓ of manganese; 100 of broken glass.

6. *White table glass.*—40 pounds of potashes; 11 of chalk; 76 of sand; ½ of manganese; 95 of white cullet.

Another.—50 of purified potashes; 100 of sand; 20 of chalk; and 2 of saltpetre.

Bohemian table or plate glass is made with 63 parts of quartz; 26 of purified potashes; 11 of sifted slaked lime, and some cullet.

7. *Crystal glass.*—60 parts of purified potashes; 120 of sand; 24 of chalk; 2 of saltpetre; 2 of arsenious acid; $\frac{1}{16}$ of manganese.

Another.—70 of purified pearlashes, 120 of white sand; 10 of saltpetre; ½ of arsenious acid; ⅓ of manganese.

A third.—67 of sand; 23 of purified pearlashes; 10 of sifted slaked lime; ¼ of manganese; (5 to 8 of red lead).

A fourth.—120 of white sand; 50 of red lead; 40 of purified pearlash; 20 of saltpetre; ⅓ of manganese.

A fifth.—120 of white sand; 40 of pearlash purified; 35 of red lead; 13 of saltpetre $\frac{1}{12}$ of manganese.

A sixth.—30 of the finest sand; 20 of red lead; 8 of pearlash purified; 2 of saltpetre; a little arsenious acid and manganese.

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A seventh.--100 of sand; 45 of red lead; 35 of purified pearlashes; $\frac{1}{7}$ of manganese; $\frac{1}{6}$ of arsenious acid.

8. *Plate glass.*—Very white sand 300 parts; dry purified soda 100 parts; carbonate of lime 43 parts; manganese 1; cullet 300.

Another.—Finest sand 720; purified soda 450; quicklime 80 parts; saltpetrre 25 parts; cullet 425.

A little borax has also been prescribed; much of it communicates an exfoliating property to glass.

Tabular view of the composition of several kinds of Glass.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
Silica - -	71·7	69·2	62·8	69·2	60·4	53·55	59·2	51·93	42·5
Potash -	12·7	15·8	22·1	8·0	3·2	5·48	9·0	13·77	11·7
Soda - -	2·5	3·0		3·0	S. pot.				
Lime - -	10·3	7·6	12·5	13·0	20·7	29·22			0·5
Alumina -	0·4	1·2		3·6	10·4	6·01			1·8
Magnesia -		2·0	2.6	0·6	0·6				
Oxyde of iron	0·3	0·5		1·6	3·8	5·74	0·4		
— manganese	0·2						1·0		
— lead -							28·2	33·28	43·5
Baryta -					0·9				

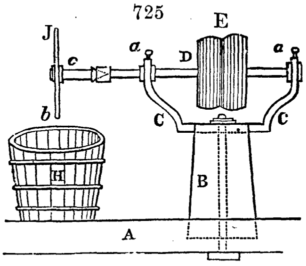
No. 1 is a very beautiful white wine glass of Neuwelt in Bohemia.
No. 2. Glass tubes, much more fusible than common wine glasses.
No. 3. Crown glass of Bohemia.
No. 4. Green glass, for medicinal vials and retorts.
No. 5. Flask glass of St. Etienne, for which some heavy spar is used.
No. 6. Glass of Sevres.
No. 7. London glass employed for chemical and physical purposes.
No. 8. English flint glass.
No. 9. Guinand's flint glass.

The manufacture of *Glass beads* at Murano near Venice, is most ingeniously simple. Tubes of glass of every color are drawn out to great lengths in a gallery adjoining the glass-house pots, in the same way as the more moderate lengths of thermometer and barometer tubes are drawn in our glass-houses. These tubes are chopped into very small pieces of nearly uniform length on the upright edge of a fixed chisel. These elementary cylinders, being then put in a heap into a mixture of fine sand and wood ashes, are stirred about with an iron spatula till their cavities get filled. This curious mixture is now transferred to an iron pan suspended over a moderate fire and continually stirred about as before, whereby the cylindrical bits assume a smooth rounded form; so that when removed from the fire and cleared out in the bore, they constitute beads, which are packed in casks, and exported in prodigious quantities to almost every country, especially to Africa and Spain.

GLASS CUTTING AND GRINDING, for common and optical purposes. By this mechanical process the surface of glass may be modified into almost any ornamental or useful form.

1. The grinding of crystal ware. This kind of glass is best adapted to receive polished facets, both on account of its relative softness, and its higher refractive power, which gives lustre to its surface. The cutting shop should be a spacious long apartment, furnished with numerous sky-lights, having the grinding and polishing lathes arranged right under them, which are set in motion by a steam-engine or water-wheel at one end of the building. A shaft is fixed as usual in gallowses along the ceiling; and from the pulleys of the shaft, bands descend to turn the different lathes, by passing round the driving pulleys near their ends.

725

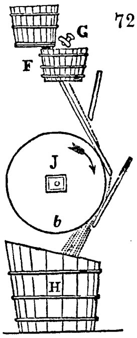


The turning lathe is of the simplest construction. *Fig.* 725, D is an iron spindle with two well-turned prolongations, running in the iron puppets *a a*, between two concave bushes of tin or type metal, which may be pressed more or less together by the thumb-screws shown in the figure. These two puppets are made fast to the wooden support B, which is attached by a strong screw and bolt to the ongitudinal beam of the workshop A. E is the fast and loose pulley for putting the athe into and out of gear with the driving shaft. The projecting end of the spindle is furnished with a hollow head-piece, into which the rod *c* is pushed tight. This rod carries the cutting or grinding disc plate. For heavy work, this rod is fixed into the head by a screw. When a conical fit is preferred, the cone is covered with lead to increase the friction.

Upon projecting rods or spindles of that kind the different discs for cutting the glass are made fast. Some of these are made of fine sandstone or polishing slate, from 8 to 10 inches in diameter, and from $\frac{3}{4}$ to $\frac{1}{2}$ inch thick. They must be carefully turned and polished at the lathe, not only upon their rounded but upon their flat face, in order to grind and polish in their turn the flat and curved surfaces of glass vessels. Other discs of the same diameter, but only $\frac{3}{4}$ of an inch thick, are made of cast tin truly turned, and serve for polishing the vessels previously ground; a third set consist of sheet iron from $\frac{1}{6}$ to $\frac{1}{2}$ an inch thick, and 12 inches in diameter, and are destined to cut grooves in glass by the aid of sand and water. Small discs of well-hammered copper from $\frac{1}{2}$ to 3 inches in diameter, whose circumference is sometimes flat, and sometimes concave or convex, serve to make all sorts of delineations upon glass by means of emery and oil. Lastly, there are rods of copper or brass furnished with small hemispheres from $\frac{1}{21}$ to $\frac{1}{4}$ of an inch in diameter, to excavate round hollows in glass. Wooden discs are also employed for polishing, made of white wood cut across the grain, as also of cork.

The cutting of deep indentations, and of grooves, is usually performed by the iron disc, with sand and water, which are allowed constantly to trickle down from a wooden hopper placed right over it, and furnished with a wooden stopple or plug at the apex, to regulate by its greater or less looseness the flow of the grinding materials. The same effect may be produced by using buckets as shown in *fig.* 726. The sand which is contained in the bucket F, above the lathe, has a spigot and faucet inserted near its bottom, and is supplied with a stream of water from the stopcock in the vessel G, which, together running down the inclined board, are conducted to the periphery of the disc as shown in the figure, to whose lowest point the glass vessel is applied with pressure by the hand. The sand and water are afterwards collected in the tub H. Finer markings, which are to remain without lustre, are made with the small copper discs, emery, and oil. The polishing is effected by the edge of the tin disc, which is from time to time moistened with putty (white oxyde of tin) and water. The wooden disc is also employed for this purpose with putty, colcothar, or washed tripoli. For fine delineations, the glass is first traced over with some colored varnish, to guide the hand of the cutter.

726



In grinding and facetting crystal glass, the deep grooves are first cut, for example the cross lines, with the iron disc and rounded edge, by means of sand and water. That disc is one sixth of an inch thick and 12 inches in diameter. With another iron disc about half an inch thick, and more or less in diameter, according to the curvature of the surface, the grooves may be widened. These roughly cut parts must be next smoothed down with the sandstone disc and water, and then polished with the wooden disc about half an inch thick, to whose edge the workman applies, from time to time, a bag of fine linen containing some ground pumice moistened with water. When the cork or wooden disc edged with hat felt is used for polishing, putty or colcothar is applied to it. The above several processes in a large manufactory, are usually committed to several workmen on the principle of the division of labor, so that each may become expert in his department.

2. *The grinding of optical glasses.*—The glasses intended for optical purposes, being spherically ground, are called lenses; and are used either as simple magnifiers and spectacles, or for telescopes and microscopes. The curvature is always a portion of a sphere, and either convex or concave. This form ensures the convergence or divergence of the rays of light that pass through them, as the polishing does the brightness of the image.

The grinding of the lenses is performed in brass moulds, either concave or convex, formed to the same curvature as that desired in the lenses; and may be worked either by hand or by machinery. A gauge is first cut out out of brass or copper plate to suit the curvature of the lens, the circular arc being traced by a pair of compasses. In this way both a convex and concave circular gauge are obtained. To these gauges the brass moulds are turned. Sometimes, also, lead moulds are used. After the two moulds are made, they are ground face to face with fine emery.

The piece of glass is now roughed into a circular form by a pair of pincers, leaving it a little larger than the finished lens ought to be, and then smoothed round upon the stone disc, or in an old mould with emery and water, and is next made fast to a holdfast. This consists of a round brass plate having a screw in its back; and is somewhat smaller in diameter than the lens, and two thirds as thick. This as-turned concave upon the lathe, and then attached to the piece of glass by drops of pitch applied to several points of its surface, taking care, while the pitch is warm, that the centre of the glass coincides with the centre of the brass plate. This serves not merely as a holdfast, by enabling a person to seize its edge with the fingers, but it prevents the glass from bending by the necessary pressure in grinding.

The glass must now be ground with coarse emery upon its appropriate mould, whether convex or concave, the emery being all the time kept moist with water. To prevent the heat of the hand from affecting the glass, a rod for holding the brass plate is screwed to its back. For every six turns of circular motion, it must receive two or three rubs across the diameter in different directions, and so on alternately. The middle point of the glass must never pass beyond the edge of the mould; nor should strong pressure be at any time applied. Whenever the glass has assumed the shape of the mould, and touches it in every point, the coarse emery must be washed away, finer be substituted in its place, and the grinding be continued as before, till all the scratches disappear, and a uniform dead surface be produced. A commencement of polishing is now to be given with pumice stone powder. During all this time the convex mould should be occasionally worked in the concave, in order that both may preserve their correspondence of shape between them. After the one surface has been thus finished, the glass must be turned over, and treated in the same way upon the other side.

Both surfaces are now to be polished. With this view equal parts of pitch and rosin must be melted together, and strained through a cloth to separate all impurities. The concave mould is next to be heated, and covered with that mixture in a fluid state to the thickness uniformly of one quarter of an inch. The cold convex mould is now to be pressed down into the yielding pitch, its surface being quite clean and dry, in order to give the pitch the exact form of the ground lens; and both are to be plunged into cold water till they be chilled. This pitch impression is now the mould upon which the glass is to be polished, according to the methods above described, with finely washed colcothar and water, till the surface become perfectly clear and brilliant. To prevent the pitch from changing its figure by the friction, cross lines must be cut in it about ½ an inch asunder, and 1-12th of an inch broad and deep. These grooves remove all the superfluous parts of the polishing powder, and tend to preserve the polishing surface of the pitch clean and unaltered. No additional colcothar after the first is required in this part of the process; but only a drop of water from time to time. The pitch gets warm as the polishing advances, and renders the friction more laborious from the adhesion between the surfaces. No interruption must now be suffered in the work, nor must either water or colcothar be added; but should the pitch become too adhesive, it must be merely breathed upon, till the polish be complete. The nearer the lens is brought to a true and fine surface in the first grinding, the better and more easy does the polishing become. It should never be submitted to this process with any scratches perceptible in it, even when examined by a magnifier.

As to small lenses and spectacle eyes, several are ground and polished together in a mould about 6 inches in diameter, made fast to a stiffening plate of brass or iron of a shape corresponding with the mould. The pieces of glass are affixed by means of drops of pitch, as above described, to the mould, close to each other, and are then all treated as if they formed but one large lens. Plane glasses are ground upon a surface of pitch rendered plane by the pressure of a piece of plate glass upon it in its softened state.

Lenses are also ground and polished by means of machinery, into the details of which the limits of this work will not allow me to enter.

Glass in the Exhibition.—So far as may be inferred, from the analysis of ordinary commercial samples of window-glass, this substance has not only a very variable composition, but, worse than this, is out of all keeping with anything like definite proportion. That it should be full of striæ, and, therefore, refract the rays of light equally, as it does, so as to produce the most hideous appearances of distortion, is a mere natural consequence of its mechanical composition, which might, and must one day, be corrected; but that whole nations should have come to view this defect as an unavoidable peculiarity, is precisely one of those surprising facts which demonstrate the influence of habit over the powers of the mind, and show how easily human reason can reconcile itself to the most gross inconsistencies. If window-glass had one uniform atomic composition, the tendency to form these striæ would nowhere exist in excess; and, therefore, their production would diminish as the skill of the workmen increased; but, with the present variable compound, the glass stretches unequally in different parts, by an equal application of force, and, in spite of human skill, presents a result alternately thick or thin, as accident determines. That these striæ have not the same composition as the parts surrounding them is very obvious, from the circumstance that, if striated glass be cut to an uniform thickness, and polished on both sides, the optical defects remain but little changed, and occasionally they are found to be increased. Again it is known, that the more complex the composition of any glass may be, the greater the liability to this striated structure,—of which flint glass offers an opposite illustration: for here, in addition to the ordinary components of glass, the silicate of lead is superadded. Now the specific gravity of silicate of lead is very high compared with that of silicate of soda, potash, or lime; hence, unless employed in the exact quantity to form a chemical combination with the other silicates, a mere mechanical mixture is produced of very different densities throughout; and the product, under the action of light, displays, permanently, that peculiar fugitive appearance, seen when syrup and water, or alcohol and water, are mixed together: that is to say, a series of curved lines are formed, by the unequal refraction of the two fluids, which entirely disappear, so soon as perfect admixture has taken place, but which remain in the case of flint glass, from the utter impossibility of affecting the necessary union between its various parts. Although, however, this cannot be done mechanically, yet, in a chemical way, nature performs such operations with ease and unerring fidelity. The French chemist, Berthier, long ago proved that many neutral salts combine together by fusion in atomic proportions, and form new, and definite compounds. Thus, carbonate of potash and carbonate of soda when mixed, atom for atom, unite and produce a compound more easy of fusion than the most fusible of the two:—similarly, either of these carbonates will act with carbonate of baryta or stronchia, and again, flour-spar and sulphate of lime, two remarkably infusible substances, when mixed, melt readily, at a low red heat, into a fluid as mobile and transparent as water. It is useless to multiply examples of this kind, for thousands exist; and the alkaline and earthy silicates form no exception to this almost universal rule. A mixture of silicate of potash and silicate of soda, will, if in atomic ratios, fuse much more readily than either of them alone. But now, let us imagine an attempt to fuse these two bodies together, in any other proportion than that in which they are naturally disposed to combine;—say that the silicate of soda is in excess: then the silicate of potash would unite with exactly sufficient of the silicate of soda to produce the extremely fusible compound above spoken of: whilst the less easily fusible silicate of soda, added in excess, would form a kind of network throughout the mass. It may be said, that a higher heat would overcome this difficulty, by thoroughly liquifying the silicate of soda; and this is really the plan now used with that view; but, independent of the fact, that the mixed silicate of potash and soda would also undergo a corresponding liquefaction, and, therefore, favour the separation of the silicate of soda; yet, as chemical union is impossible, from the very conditions of the experiment, even the most perfect mechanical mixture, under the greatest advantages of fluidity, would never generate a homogeneous body. The striæ might, indeed, be diminished in size; but this would imply a corresponding increase in their number; and, if carried very far, complete opacity would result from such an endeavour to subvert the laws of nature. The power of the workmen to remedy this defect is therefore limited to the capability of modifying its more salient features; he can neither remove nor destroy it. What we have here illustrated by the simplest of all assumptions, gathers and accumulates into a formidable evil, when several silicates are fused together, having considerable differences of specific weight. Thus, in the case of flint glass before alluded to, there are generally three, and sometimes five, of these silicates fused together, into, probably, one of the most antagonistic compounds that could be conceived, refracting and dispersing the ray of light in fifty different directions, and demonstrating the unfriendly nature of its coerced union, by flying in pieces from the most trivial applications of heat or violence. Yet in flint-glass we are not surpassed, nor indeed equalled, by any other nation; and so thoroughly has this beautiful substance become associated with our industrial reputation, that the name, flint-glass, has been adopted into several continental languages. Nevertheless, it cannot be doubted that a wide field of improvement is open in this quarter, and that some more solid foundation is needed by our manufacturers in this line, than the prestige of a name, or the force of capital.

In our concluding remarks we shall point out the direction in which improvement is practicable; and at present it may not be uninteresting to examine the contents of the Great Exhibition in respect to this kind of glass. The display of goods by Messrs. Apsley, Pellatt and Co., is alone sufficient to exhaust the entire subject of flint-glass; and the mere inquirer into this branch of manufacture need go no farther to get a perfect conception of the wonders that can be achieved by the manipulation of this material. The coup d'œil is certainly most beautiful; but, supported as it is and multiplied by the rival exhibitions of Messrs. Osler, Harris, Bacchus, Powell, Lloyd and Summerfield, and a host of others, the effect is positively dazzling and gorgeous. At a distance sufficient to cover the faults of refraction, not even the diamond itself has a more pleasing appearance; and indeed, the glass *koh-i-noor* of Mr. Pellatt, displayed in the gallery, might be substituted for the real gem, shown in the main avenue, without the least risk of detection on the part of the million, or any great loss of brilliancy to the most practised eye,—so perfect is the imitation. Is it not then to be deplored, that science has had no hand in mingling its constituents together? But we must turn from this glittering assortment and descend to a lower level, where we shall find Great Britain in disgrace, and suffering severely from comparison with a rival inferior in capital and natural resources, but conscious of power through the aid of real knowledge, and triumphantly asserting a claim to supremacy in the very perfection of the glass-maker's art. The plate-glass of France casts that of England far into the shade. The productions of St. Gobain stand alone in the Exhibition; they have no competitors; and we are in a condition to prove that chemistry has done this. The plate-glass of Montluçon, too, adds to the defeat. In examining the refractive aberrations of a mirror, the spectator will find his task facilitated by standing so that the rays of light from any geometrically shaped body fall upon the glass, at an angle of 25°; when, of course, they will be reflected towards his eye at the same angle. Now gazing intently on the figure in question—and which, in the Exhibition, may be one of the parallelograms formed by the rafters of the roof, let him gently move his head from one side to the other. If the glass be of English manufacture, he will immediately perceive a tumultuous movement in the lines of the figure, as if this were subjected to an undulatory action,—the lines, before straight and parallel, become crooked and convergent in places, and minute objects lose entirely their outline and definition. In the case of the St. Gobain glass, shown in the French department, nothing of this kind takes place. As it can serve no good purpose to dwell upon each individual example of imperfection, we refrain from entering further into the comparative merits of the British exhibitors. They are all surpassed by the French makers, both in respect to uniformity of composition and fineness of polish. The St. Gobain Company having had the good sense to place a number of small samples of their glass for the acceptance of those visitors who may feel an interest in the manufacture, we have selected and analyzed one of these little squares, and shall presently detail the result; but our object in alluding to them here is, that glass-makers themselves may procure one of these specimens and contrast it with a like morsel of English plate-glass. If the two be laid side by side upon any moderately light-coloured ground, and a distant object, as a chimney for example, be subjected to reflection, it will be found, that whilst the French glass gives a clear sharp outline, the English reflects either two or more images in a hazy and imperfect manner. There is no getting over this fact; and therefore improvement is imperative. The mode of making plate-glass being, so to say, identical in the two countries, the difference here remarked can arise from nothing else than a difference in composition.

In France, as in England, the ingredients are mixed with some care, and introduced into a crucible, heated by a powerful furnace. These ingredients are sand or silica, carbonate of soda, and carbonate of lime, with perhaps a little ground felspar in some cases. The carbonate of soda is first attacked by the silica, and its carbonic acid driven off, whilst the remaining silica and carbonate of lime becomes imbedded in the vitrifying mass. As the heat increases, a more perfect fusion takes place; and then the carbonic acid of the carbonate of lime makes its way through the fused materials by which they are mechanically mingled together during the effervescence, which is technically termed the "boil;" and, provided no after separation ensues from the process of "settling," the whole crucible or "pot" of glass will have a uniform composition, But, as we have seen, this depends altogether upon the relative proportion of the materials towards each other, for an excess of either one or other of the bases will destroy the homogeneous character of the whole, and introduce a plexus of striæ. Now the plate-glass of St. Gobain is almost exactly an atomic compound, and consists of one atom of the trisilicate of soda and one atom of the trisilicate of lime, with a small per-centage of alumina. The union is therefore complete; and when it is remembered that the celebrated French chemist, Gay Lussac, was regularly employed as an adviser to this company, and that his son, M. Jules Lussac, retains that appointment to this day, it is not very surprising that our manufacturers are defeated in the article of plate-glass. Science must ever take the lead of prejudice and custom.

The examination of English plate-glass fully corroborates the general result deduced from the action of light. There is no approach to an atomic arrangement. The principal constituent is trisilicate of soda, but variable quantities of lime, alumina, and even magnesia, exist in it. Potash is sometimes present, and oxide of iron is invariably so; but in not one single instance, out of 17 samples examined with great care, could so much as a surmise of the doctrine of combining proportions be gathered from the result of the analyses. Similarly fruitless was a research instituted upon flint-glass, both British and foreign. Of 35 samples analyzed, no satisfactory evidence could be adduced to favour the opinion that science had been a helpmate to industry, or was at all concerned in this branch of manufacture. There are, however, some points of vast interest associated with the practical working out of this matter. Potash is known to give a more brilliant and harder glass than soda, and alumina seems to tend in the same direction. The Bohemian glass, so celebrated throughout Europe, is a glass of this description, and contains silicate of alumina, silicate of lime, and silicate of potash, but not in chemical proportions. This glass is therefore striated, as may be seen by examining that in the Austrian department; but it seems to permit of a more perfect decoration by metallic oxides than can be developed in glass of lime and soda. This very probably depends upon the alumina contained in it. From some singular oversight, the use of carbonate of baryta has not yet found its way into the composition of glass, though we can scarcely conceive a more hopeful material. This substance may be had in large quantity in the North of England, of great purity, and at a merely nominal cost as compared with its value for such a purpose as glass-making That it would fuse readily with a due amount of soda, and give "a boil" as well as chalk, there can be no doubt; whilst its great density will certainly improve the refractive power of the resulting product, and thus rival the brilliancy of lead or flint-glass, without imparting that softness and liability to receive scratches which are so objectionable in the latter variety. One difficulty may perhaps reside in the want of information concerning the quantity to be employed. But this is easily adjusted; for it has been demonstrated that, during vitrification, the silicic acid unites to bases in the proportion of three atoms to one: consequently three atoms, or 138 parts, will always require one atom of each base. Therefore, this weight of good dry sand may be set against 54 of dry carbonate of soda, 70 of carbonate of potash, 50 of pure marble or chalk, 99 of carbonate of baryta, and 112 of oxide of lead or litharge. Suppose, then, that the object is to employ carbonate of baryta for the first time, here 6 atoms or 276 parts of sand, 1 atom or 54 parts of dry carbonate of soda, and 1 atom or 99 parts of carbonate of baryta, may be mixed and fused together with every prospect of obtaining a good result; or 9 atoms of silica, 1 of carbonate of potash, 1 of carbonate of soda, and 1 of carbonate of baryta, might be tried without fear of failure. Again, in the case of flint-glass, 112 of litharge, 54 of soda, and 276 of sand, would probably succeed, or an additional atom of trisilicate of potash might be used. For many years past, M. Dumas, now, perhaps, the first chemist in France, has been in the habit of demonstrating to his pupils that glass of all kinds, when properly made, must necessarily be an atomic compound; and yet we scarcely expect to find a single British glass-maker who will admit that his art is susceptible of such decisive and beautiful simplification.

To assist as far as we can in the attainment of this end, we shall proceed to describe a simple means for the analysis of glass, which will enable any person, possessed of even very trifling chemical skill, to determine the composition of any given sample of glass in a comparatively short time. From the nature of the material, it becomes necessary to divide the analysis into two distinct portions; one of which has for its object the estimation of its alkaline ingredients, the other that of the earthy, metallic, and siliceous matters. Having heated a sufficient quantity of the sample in question to dull redness, it must be suddenly thrown, whilst still hot, into a basin containing cold water. In this way it becomes cracked and flawed in all directions, so as to favour its reduction into powder. When dry it must, therefore, be carefully ground in an agate or steel mortar, until it has the appearance of fine flour. Nor is it a matter of indifference whether this takes place in contact with water or not; for glass, in this extreme state of comminution, readily gives up a part of its alkali to water; and hence, if ground in the presence of that fluid, the resulting analysis would prove incorrect. But we will suppose that a quantity of finely powdered glass has been obtained as above indicated, and the amount of its alkali is desired; then weigh out 100 grains of the glass, and carefully mix with it 200 grains of pure fluor spar in a similarly powdered condition. Place the mixture in a platinum or leaden vessel, and pour over it 500 grains of strong sulphuric acid,—stirring the whole well together with a silver spoon; but taking care not to remove any portion of the materials. Next, apply a heat of about 212° Fahr.; and as the process draws to a conclusion, this may be raised as high as 300°. When all evolution of gaseous fumes has ceased, water may be poured on the residuary mass to the extent of four or five ounces, and the mixture thrown on a filter. After the clear fluid has passed through, a little more water must be added to the filter, so as to wash out the whole of the soluble matter; these washings being joined to the original clear fluid, which consists of sulphate of soda or potash, or both, with a quantity of sulphate of lime, and perhaps also of magnesia and alumina. To this an excess of carbonate of ammonia must now be added, to admit of the separation of the earthy salts being effected by filtration. The clear solution is next boiled down to dryness, and the residue is heated red-hot for a minute or two. This residue is the soda or potash, or both, formerly contained in 100 grains of the glass, but now united to sulphuric acid. Having ascertained its weight, the relative proportions of potash and soda may be found by testing its content of sulphuric acid with a barytic solution, and calculating the result by the well-known Archimedean equation; or by dissolving the mixed salt in a small quantity of water, and, after adding an excess of tartaric acid, leaving the whole for a few hours covered up in a cool place. Almost the whole of the potash will separate in this way as bitartrate of potash. The quantity of alkali may be determined from the atomic constitution of the alkaline salts. Thus, supposing the dry residue altogether composed of sulphate of soda, then as 72 grains of it indicate 32 of pure soda, the result may be obtained by the rule of proportion. The amount of alkali being known, another portion of the powdered glass must be employed for ascertaining the remainder of the ingredients. That is to say, 100 grains of the sample must be mixed with 200 grains of pure potash, and the whole fused together in a silver crucible, at a red heat, until perfect liquefaction ensues, when the crucible and its contents may be withdrawn from the fire, and, as soon as cool enough, boiled in half-a-pint of pure water, so as thoroughly to dissolve the fused mass from the crucible. An excess of nitric acid being poured into the solution, the mixture is then evaporated to dryness, by which means the silicic acid is rendered insoluble; consequently, on the application of water, this remains, and may be dried and weighed, whilst the lime, alumina, and lead of the glass may be separated from the soluble portion by the addition, first, of sulphuretted hydrogen, which separates the lead, then of ammonia, which throws down the alumina, and, next, by pouring in carbonate of ammonia, which precipitates the lime as a carbonate. Thus, therefore, the alkaline matters are found by one process, and the silica, earthy, and metallic constituents by another, both of which may be conducted at the same time. It has been recommended to employ carbonate of baryta in the analysis of glass; but the high temperature required with this substance dissipates a portion of the alkaline components, and thus leads to serious errors. Even mere fusion in a glass furnace expels soda from glass, and renders it more and more infusible; but this expulsion is much favoured by the presence of baryta. The above method of analyzing glass is, therefore, to be preferred to the baryta plan, by individuals not habitually engaged in manipulative chemistry. Until manufacturers adopt the custom of examining every specimen of glass they make, the chances of improvement are extremely limited; for success one day is constantly followed by failure in another, without any means of checking or controlling the manufacture. It is generally said that the best glass is made during cold weather, as at this time the furnaces give most heat, from the increased activity of the draught, through the augmented barometrical pressure. The assertion itself is most likely true; but the explanation of its cause leaves much to be elucidated, even if a higher heat prevails at the period in question. Admitting the beneficial agency of a high temperature, or "sharp fire," as it is termed, this perhaps depends upon the sudden fusion of the materials before the carbonic acid of either of the carbonates has had time to escape; consequently, a much more active "boil" and thorough intermixture must occur under such circumstances than where this gas has been suffered to pass off in great part before fusion. This, however, would only diminish the individual size of the striæ by multiplying their number; and such glass must, even under the most favourable circumstances, suffer greatly by comparison with that of St. Gobain. Nor can improvement be hoped for until, as in France, in this particular case, science is linked hand in hand with manufacturing industry. Since the grand discovery made by Dalton, that Nature works in definite proportions, there can be no excuse for continuing to follow the doctrine of chance, with its occasional successes and frequent failures—the alternations of hope and despair. The laws which regulate the entire universe are not more immutable than those which tend to unite silica and soda in equivalent proportions. It is, therefore, simply futile to battle with such a power; for even when success seems on the point of attainment, we find Nature reasserting her dominion, and stamping those works of man which have been pursued in defiance of her laws with the indelible impress of imperfection and error.

That glass of all kinds may be made in this country quite equal to that of St. Gobain, is saying no more than that Nature's laws are universal. But, remembering the great facilities we possess as a glass manufacturing nation, the attainment even of such a result is but a sorry flight of ambition. We are placed in a position which demands from us something more than mediocrity or successful competition, as no nation in the world possesses the same amount of natural advantages. In fuel, in soda, in sand, in chalk, in litharge, we are naturally rich to overflowing. Our capital and commerce give us the command of every market; our manufacturers need only ask and have. So long as a miserable fiscal impost sat like an incubus upon the back of the glass-making interest, inferiority was unavoidable; but the humiliating aspect of the British plate glass throughout the Great Exhibition is scarcely palliated by this excise reminiscence; and we refrain from terming it a national disgrace only under a belief that already improvement has begun, which will thrust these specimens into the oblivious records of the past.

An Achromatic Telescope of gigantic dimensions and powers, which is now being constructed for the Rev. Mr. Craig, Vicar of Leamington, under the superintendence of W. Cravatt, Esq. F.R.S., has been the occasion of the manufacture of some admirable optical flint object glasses at the great works of Messrs. Chance, of Birmingham. It is 24 inches in diameter, and is perfectly clear and homogeneous in structure. The crown glass lens, of like size, is of plate glass, cast by the Thames Plate-glass Company. The total length of the telescope in use will be 85 feet, but the real focal length of the lens is much less, being probably about 76 feet. A quarter of an inch letter can be read with this telescope, even in its imperfect state, at the distance of half a mile. It promises to be as powerful as Lord Rosse's colossal reflector, and it is mounted, in its observatory, on Wandsworth Common on such mechanical principles, as to be moveable in any direction with the slightest touch of the finger, while it can be directed to objects at 80° of elevation above the horizen. The weight of the tube is 3 tons; it is quite inflexible and free from tremor or vibration. The chain by which the tube is lowered or raised, is capable of raising a weight of 13 tons. A gentle touch on the wheel of the iron railway, on which it moves, lifts 20 cwt.

Glass from Alkaline Sulphates. Messrs. Balmain and Parnell have patented a process for making glass from alkaline sulphates, in which they first make a silicate by igniting sulphate of soda with sand and charcoal powder, for example, so as to contain from about 12 to 20 per cent. of alkali. To make a silicate of about 20 per cent. of soda, they mix 3 cwt. of sand, 2 cwt. of dry sulphate of soda in fine powder, and from 16 to 18 lbs. of finely ground charcoal, and heat the mixture to whiteness in a furnace. As the silicate falls from the furnace it is received into a vessel of water, which renders it more easy to grind, and by dissolving the excess of sulphate, presents that substance in a convenient form for being recovered. To make a silicate of soda of 12 per cent. of soda, 3 parts of sand and 1 part of sulphate of soda are mixed, and the mixture is heated, with occasional stirring, in the furnace. By exposure to a low red heat for from 6 to 10 hours, a perfect silicate of soda will be formed. A silicate of potash of 26 per cent. is made by heating 3½ cwt. of sand, 2½ cwt. of sulphate of potash, and 18 pounds of charcoal. Sometimes both a sulphate and carbonate of a base are used together; and sometimes two bases are used to make a double silicate.

In all cases, chemical equivalents are observed; a single equivalent of charcoal to one of sulphate. To make a double silicate of soda and barytes, either of the following mixtures may be used:—

No. 1., 273 parts of sand, 72 sulphate of soda, 117 sulphate of barytes, and 12 charcoal. No. 2., 273 sand, 72 sulphate of soda, 99 carbonate of barytes, and 6 charcoal. A flow of sulphate indicates want of charcoal, and a brown colour in the result an excess of charcoal; but both of these accidents may be produced by too low a heat in the furnace. The highest working temperature is a fair white heat. The addition of 5 or 10 per cent. of common salt aids the fluxing, and is not hurtful to the result. The sulphate should be in fine powder. The patentees also use a sulphuret or hyposulphite as a decomposing agent for the sulphates instead of charcoal. Half an equivalent proportion of sulphuret, or a single equivalent of hyposulphite, should be used in the place of each equivalent of the charcoal; as, for example, 20 parts of sulphuret of sodium for 6 parts of charcoal. These decompositions and combinations are effected by means of a peculiar reverberatory furnace, with two inclined beds or flues through which the fire passes and plays.—*Newton's Journal*, xxxv. 223.

The duties payable in the United Kingdom, upon the different descriptions of glass are, for:—

	£	s.	d.	
Window glass, any kind, not exceeding $\frac{1}{9}$ inch thickness - - - - - -	0	3	6	per cwt.
All glass exceeding $\frac{1}{9}$ inch thickness, and all silvered or polished glass, superficial measure: - - - - - -				
Not exceeding 9 square feet - -	0	0	3	per square foot
Exceeding 9 and not 14 square feet -	0	0	6	—
— 14 „ 36 „ -	0	0	7½	—
— 36 and upwards - -	0	0	9	—
Painted or ornamented - - -	0	0	9	per superficial foot.
All white flint glass bottles, not cut, engraved, or otherwise ornamented, and beads and bugles - - - - - -	0	0	0½	per lb.
Wine glasses, tumblers, and all other white flint glass goods not cut, engraved, or otherwise ornamented - - - - -	0	0	1	—
All flint cut glass, flint coloured glass, and fancy ornamental glass - - - -	0	0	2	per lb.

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	£	s.	d.	
Bottles of glass covered with wicker (not being flint or cut glass), or of green or common glass - - - - - -	0	0	9	per cwt.
Unenumerated, and old broken glass - -	0	3	6	per cwt.

Glass, Austrian. M. Peligot states that the hard glass of Bohemia is composed of 100 parts of silica, 12 parts of quicklime, and only 28 parts of carbonate of potash. These proportions give a glass quite unmanageable in ordinary furnaces; but the addition of a comparatively small quantity of boracic acid is capable of determining fusion, and the result is a glass having all the requisite limpidity at a high temperature and possessing at the same time a great brilliancy and hardness.

Glass, Bohemian. Glasses are silicates which must contain at least 50 per cent. of silica; the more there is of it, the more perfect, unalterable, hard, and infusible is the glass. The hardest, most beautiful, and most perfect glass, is found in nature in the state of pure silica in rock crystal. To render silica fusible, certain fluxes must be added: these fluxes are potassa, soda, lime, and oxide of lead.

Silica fuses very well with the alkalis, but the resulting glass is rapidly changed by absorbing moisture from the air. To prevent this alteration, it is always necessary, in the manufacture of glass, to introduce a certain quantity of lime or of oxide of lead.

In the following table is given the analyses of a certain number of Bohemian glasses, which will indicate their composition with precision.

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)
Silica - - - - - -	71·6	71·7	69·4	62·8	75·9	78·85	70·	57·
Potassa - - - - -	11·0	12·7	11·8	22·1	- -	5·5	20·	25·
Soda - - - - - -	- -	2·3	- -	- -	17·5	12·05		
Lime - - - - - -	10·	10·3	9·2	12·5	3·8	5·6	4·	12·5
Magnesia - - - -	2·3							
Alumina - - - -	2·2	0·4	9·6	2·6	2·8	3·5	5·	3·
Oxide of Iron - - -	3·9	0·3	- -	- -	- -	- -	0·6	1·3
Oxide of Manganese -	0·2	0.2	- -	- -	- -	- -	0·4	0·4
	101·2	98·1	100·	100·	100·	100·5	100·	99·2

(1.) Bohemian glass from Neufeld, (M. Grus); its composition is represented, nearly, by the formula, $Ca\ S^5 + (Al\ F)\ S^5 + (K\ Mg\ Mn)\ S^5$.

(The reader will remember, that these are mineralogical, and not chemical, symbols; since the letters signify the oxides, or acids, and not the elementary bases, as they would in chemistry.—*Trans.*)

(2.) A fine table glass from Neuwelt (M. Berthier); it is exceedingly beautiful, and is prepared, according to M. Perdonnet, with a mixture of 100 quartz, 50 caustic lime, 75 carbonate of potassa, and a very small quantity of nitre, arsenious acid, and oxide of manganese. The presence of arsenic cannot be detected by analysis. The composition of this glass is expressed by the formula $C\ S^6 + (K\ N)\ S^6$.

(3.) Old Bohemian glass, (M. Dumas); its formula is $(Al\ C\ K)\ S^4$.

(4.) Crown glass of German manufacture, (M. Dumas); its composition is expressed by the formula $(K\ C)\ S^4$.

(5.) Glass for mirrors, (M. Dumas); it is represented by the formula $(N\ Al\ C)\ S^6$.

(6.) Another glass for mirrors, (M. Dumas); its formula lies between $B\ S^5$ and $B\ S^6$.

(7.) White table glass, from Silberberg near Gratzen; its composition is exactly expressed by the formula, $2\ (K\ Ca)\ S^5 + (Al\ F)\ S^5$.

(8.) Mirror glass from New-Hurkenthal, for the manufacture of cast mirrors. It shows a greenish tint in section, and softens at a gentle heat. Its composition is nearly represented by the formula $(Al\ F)\ S^3 + 6\ (K\ C\ M)\ S^3$, or more simply $(K\ C\ Al)\ S^3$.

Properties of Glass, Transparence, Colourlessness.—Transparence and colourlessness are the first properties of glass: to obtain them, the materials must be employed extremely pure, and the least possible flux added; an excess of potassa gives the glass a greenish tint; soda and its salts give it a yellow tint, and lime renders it milky. A very small quantity of the sulphate of potassa, or soda, gives it a yellowish, or blackish, brown green; iron colours it strongly bottle green; and an excess of the manganese employed to remove the coloration due to the oxide of iron, gives it a bluish tint, which becomes a decided violet by the action of the solar light. If the minium employed in the manufacture of crystal contains a little copper, which very often happens, the crystal takes a slight emerald green tint; this, however, is not to be feared in Bohemia, where there is but a single establishment which makes lead glass.

Charcoal colours glass of a topaz yellow, more or less dark, and sometimes reaching a purple, so that it is impossible to obtain a perfectly colourless glass in furnaces which smoke, or in those which are heated by turf, lignite, or bituminous coal; and in these cases it is necessary to employ covered crucibles, as is done in the manufactory of crystal at Choisy-le-Roi; it is also necessary on this account, when in the fabrication of glass the alkaline carbonates are replaced by sulphate of soda, to add in the crucible a little (about $\frac{1}{13}$) less of carbon than would be necessary to reduce the sulphate completely, and even thus but common glass is obtained by this process, since the slight excess of sulphate of soda, which must be left, gives a blackish brown tint.

Hardness, Elasticity.—The Bohemian glass is, within certain limits, perfectly elastic, and very sonorous; when well made, it is sufficiently hard to strike fire with steel, and is scratched with difficulty. The lead glasses, on the other hand, have but little hardness, and less in proportion as they contain more oxide of lead; besides which they rapidly lose their brilliancy by use.

Fusibility, Cooling, Annealing, Devitrification.—All glass is more or less fusible; when it is softened by the action of heat, it may be worked with the greatest ease, and may be drawn out into threads as fine as those of the cocoon of the silkworm. Glass, when it is submitted to rapid cooling, becomes very fragile, and presents several very remarkable phenomena, among which I will cite as an example Prince Rupert's drops. Glass supports variations of temperatures better in proportion as it has been more slowly cooled; thus, when it has been but slightly annealed, or not at all, its fragility may be considerably diminished by annealing it in water, or better, in boiling oil.

All glass exposed during a longer or shorter time to a heat sufficiently elevated, loses its transparency, and becomes extremely hard, and much less brittle than before. There takes place a phenomenon precisely similar to that which we see taking place every day, by the slow cooling of the slags of our smelting furnaces, and especially in volcanic lavas. Glass with a soda base is more fusible and less hard than that whose base is potassa.

Density.—Below is given the density of several glasses without lead:—

Old Bohemian glass (Dumas) - - - - -	2·396
Bohemian bottle glass - - - - - -	3·782
do. window glass - - - - - -	2·642
Fine glass, called Bohemian crystal - - - - -	2·892
Mirror glass of Cherbourg, (Dumas) - - - - -	2·506
do. St. Gobain - - - - - - - -	2·488
do. Newhaus 1812, (Scholz) - - - - -	2·551
do. do. 1830. - - - - - -	2·653

Action of Atmospheric and Chemical Agents.—The harder and more infusible a glass is, the less is it alterable by the action of atmospheric and chemical agents, with the exception of hydrofluoric acid. Glass which is too alkaline attracts gradually the moisture of the air and loses its lustre and polish. Many glasses are perceptibly attacked by a prolonged boiling with water, and *à fortiori* by acid and alkaline solutions; thus, the bottle glass is frequently attacked by the tartar which is found in the wine. According to Guyton Morveau all glass which is attacked by prolonged boiling with concentrated solutions of alum, common salt, sulphuric acid, or potassa, is of bad quality.

The silica which is employed in Bohemia in the manufacture of glass, is obtained by calcining crystalline quartz, and afterwards pounding it while dry. When the quartz has been heated to a cherry-red, it is withdrawn from the fire, and thrown immediately into cold water.

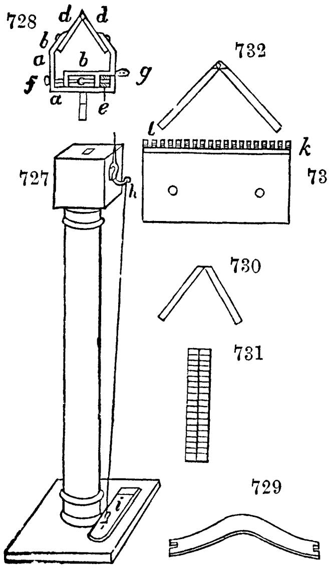
Almost all the Bohemian glass is a potash glass, because soda and its salts give to glass a sensible yellowish tint. The limestone which is used is as white as Carrara marble. The clay employed for the crucibles is very white, and consists of silica $45\frac{8}{10}$, alumina $40\frac{4}{10}$, and water $13\frac{8}{10}$.

GLAUBER SALT is the old name of sulphate of soda.

GLAZES. See Pottery.

GLAZIER, is the workman who cuts plates, or panes of glass, with the diamond, and fastens them by means of putty in frames or window casements. See Diamond, for an explanation of its glass-cutting property.

GLOVE MANUFACTURE. In February, 1822, Mr. James Winter of Stoke under-Hambdon, in the county of Somerset, obtained a patent for an improvement upon



a former patent machine of his for sewing and pointing leather gloves. *Fig.* 727 represents a pedestal, upon which the instrument called the jaws is to be placed. *Fig.* 728 shows the jaws, which instead of opening and closing by a circular movement upon a joint as described in the former specification, are now made to open and shut by a parallel horizontal movement, effected by a slide and screw; *a a* is the fixed jaw, made of one piece, on the under side of which is a tenon, to be inserted into the top of the pedestal. By means of this tenon the jaws may be readily removed, and another similar pair of jaws placed in their stead, which affords the advantage of expediting the operation by enabling one person to prepare the work whilst another is sewing; *b b* is the moveable jaw, made of one piece. The two jaws being placed together in the manner shown at *fig.* 728, the moveable jaw traverses backwards and forwards upon two guide-bars, *c*, which are made to pass through holes exactly fitted to them, in the lower parts of the jaws. At the upper parts of the jaws are what are called the indexes, *d d*, which are pressed tightly together by a spring, shown at *fig.* 729, and intended to be introduced between the perpendicular ribs of the jaws at *e*. At *f* is a thumbscrew, passing through the ribs for the purpose of tightening the jaws, and holding the leather fast between the indexes while being sewn; this screw, however, will seldom, if ever, be necessary if the spring is sufficiently strong; *g* is an eye or ring fixed to the moveable jaw, through which the end of a lever, *h*, in *fig.* 727 passes; this lever is connected by a spring to a treadle, *i*, at the base of the pedestal, and by the pressure of the right foot upon this treadle, the moveable jaw is withdrawn; so that the person employed in sewing may shift the leather, and place another part of the glove between the jaws. The pieces called indexes are connected to the upper part of the jaws, by screws passing through elongated holes which render them capable of adjustment.

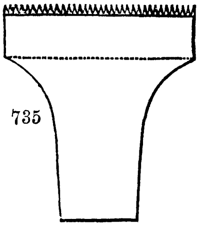
The patentee states, that in addition to the index described in his former patent, which is applicable to what is called round-seam sewing only, and which permits the leather to expand but in one direction when the needle is passed through it, namely, upwards, he now makes two indexes of different construction, one of which he calls the receding index, and the other the longitudinally grooved index. *Fig.* 730 represents an end view, and *fig.* 731 a top view of the receding index, which is particularly adapted for what are called "drawn sewing, and prick-seam sewing;" this index, instead of biting to the top, is so rounded off in the inside from the bottom of the cross grooves, as to permit the needles, by being passed backwards and forwards, to carry the silk thread on each side of the leather without passing over it. *Fig.* 732 represents an end view of the longitudinally grooved index, partly open, to show the section of the grooves more distinctly; and *fig.* 733 represents an inside view of one side of the same index, in which the longitudinal groove is shown passing from *k* to *l*. This index is more particularly adapted to round seam sewing, and permits the leather to expand in every direction when the needle is passed through it, by which the leather is less strained, and the sewing consequently rendered much stronger.

It is obvious that the parallel horizontal movement may be effected by other mechanical means besides those adopted here, and the chief novelty claimed with respect to that movement, is its application to the purpose of carrying the index used in sewing and pointing leather gloves.

Importation of leather gloves for home consumption; and amount of duty in

1836.	1837.	1836.	1837.
1,461,769.	1,221,350.	£27,558.	£22,923.

GLOVE-SEWING. The following simple and ingenious apparatus, invented by an Englishman, has been employed extensively in Paris, and has enabled its proprietors to realize a handsome fortune. The French complain that "it has inundated the world with gloves, made of excellent quality, at 30 per cent. under their former wholesale



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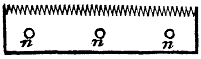

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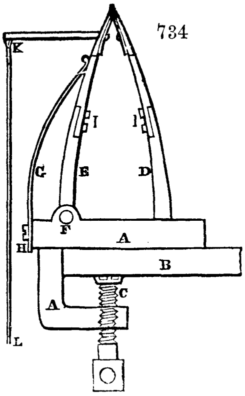

734

prices." The instrument is shown in profile ready for action in *fig.* 734. It resembles an iron vice, having the upper portion of each jaw made of brass, and tipped with a kind of comb of the same metal. The teeth of this comb, only one twelfth of an inch long, are perfectly regular and equal. Change combs are provided for different styles of work. The vice A A is made fast to the edge of the bench or table B, of the proper height, by a thumb-screw C, armed with a cramp which lays hold of the wood. Of the two jaws composing the machine, the one D is made fast to the foot A A, but the other E is moveable upon the solid base of the machine, by means of a hinge at the point F. At I I is shown how the upper brass portion is adjusted to the lower part made of iron; the two being secured to each other by two stout screws. The comb, seen separately in *fig.* 736, is made fast to the upper end of each jaw, by the three screws *n n n*. *Fig.* 735 is a front view of the jaw mounted with its comb, to illustrate its construction.

The lever K corresponds by the stout iron wire L, with a pedal pressed by the needlewoman's foot, whenever she wishes to separate the two jaws, in order to insert between them the parallel edges of leather to be sewed. The instant she lifts her foot, the two jaws join by the force of the spring G, which pushes the moveable jaw E against the stationary one D. The spring is made fast to the frame of the vice by the screw H.

After putting the double edge to be sewed in its place, the woman passes her needle successively through all the teeth of the comb, and is sure of making a regular seam in every direction, provided she is careful to make the needle graze along the bottom of the notches. As soon as this piece is sewed, she presses down the pedal with her toes, whereby the jaws start asunder, allowing her to introduce a new seam, and so in quick succession.

The comb may have any desired shape, straight or curved; and the teeth may be larger or smaller, according to the kind of work to be done. With this view, the combs might be changed as occasion requires; but it is more economical to have sets of vices ready mounted with combs of every requisite size and form.

GLUCINA (*Glucine*, Fr.; *Berryllerde*, Germ.), is one of the primitive earths, originally discovered by Vauquelin, in the beryl and emerald. It may be extracted from either of these minerals, by treating their powder successively with potash, with water, and with muriatic acid. The solution by the latter, being evaporated to dryness, is to be digested with water, and filtered. On pouring carbonate of ammonia in excess into the liquid, we form soluble muriate of ammonia, with insoluble carbonates of lime, chrome, and iron, as also carbonate of glucina, which may be dissolved out from the rest by an excess of carbonate of ammonia. When the liquid is filtered anew, the glucina passes through, and may be precipitated in the state of a carbonate by boiling the liquid, which expels the excess of ammonia. By washing, drying, and calcining the carbonate, pure glucina is obtained. It is a white insipid powder, infusible in the heat of a smith's forge, insoluble in water, but soluble in caustic potash and soda; as also, especially when it is a hydrate, in carbonate of ammonia. It has a metallic base called glucinum, of which 100 parts combine with 45·252 of oxygen to form the earth. It is too rare to be susceptible of application in manufactures.

GLUCOSE. The name given to grape and starch sugar by M. Dumas.

GLUE (*Colle forte*, Fr.; *Leim*, *Tischlerleim*, Germ.) is the chemical substance gelatine in a dry state. The preparation and preservation of the skin and other animal matters employed in the manufacture of glue, constitute a peculiar branch of industry. Those who exercise it should study to prevent the fermentation of the substances, and to diminish the cost of carriage by depriving them of as much water as can conveniently be done. They may then be put in preparation by macerating them in milk of lime, renewed three or four times in the course of a fortnight or three weeks. This process is performed in large tanks of masonry. They are next taken out with all the adhering lime, and laid in a layer, 2 or 3 inches thick, to drain and dry, upon a sloping pavement, where they are turned over by prongs two or three times a day. The action of the

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lime dissolves the blood and certain soft parts, attacks the epidermis, and disposes the gelatinous matter to dissolve more readily. When the cleansed matters are dried, they may be packed in sacks or hogsheads, and transported to the glue manufactory at any distance. The principal substances of which glue is made are the parings of ox and other thick hides, which form the strongest article, the refuse of the leather dresser; both afford from 45 to 55 per cent. of glue. The tendons, and many other offals of slaughter-houses, also afford materials, though of an inferior quality, for the purpose. The refuse of tanneries, such as the ears of oxen, calves, sheep, &c., are better articles; but parings of parchment, old gloves, and, in fact, animal skin in every form, uncombined with tannin, may be made into glue.

The manufacturer who receives these materials is generally careful to ensure their purification by subjecting them to a weak lime steep, and rinsing them by exposure in baskets to a stream of water. They are lastly drained upon a sloping surface, as above described, and well turned over till the quicklime gets mild by absorption of carbonic acid; for, in its caustic state, it would damage the glue at the heat of boiling water. It is not necessary, however, to dry them before they are put into the boiler, because they dissolve faster in their soft and tumefied state.

The boiler is made of copper, rather shallow in proportion to its area, with a uniform flat bottom, equably exposed all over to the flame of the fire. Above the true bottom there is a false one of copper or iron, pierced with holes, and standing upon feet 3 or 4 inches high; which serves to sustain the animal matters, and prevent them from being injured by the fire. The copper being filled to two-thirds of its height with soft water, is then heaped up with the bulky animal substances, so high as to surmount its brim. But soon after the ebullition begins they sink down, and, in a few hours, get entirely immersed in the liquid. They should be stirred about from time to time, and well pressed down towards the false bottom, while a steady but gentle boil is maintained.

The solution must be drawn off in successive portions; a method which fractions the products, or subdivides them into articles of various value, gradually decreasing from the first portion drawn off to the last. It has been ascertained by careful experiments that gelatine gets altered over the fire very soon after it is dissolved, and it ought therefore to be drawn off whenever it is sufficiently fluid and strong for forming a clear gelatinous mass on cooling capable of being cut into moderately firm slices by the wire. This point is commonly determined by filling half an egg-shell with the liquor, and exposing it to the air to cool. The jelly ought to get very consistent in the course of a few minutes; if not so, the boiling must be persisted in a little longer. When this term is attained, the fire is smothered up, and the contents of the boiler are left to settle for a quarter of an hour. The stop-cock being partially turned, all the thin gelatinous liquor is run off into a deep boiler, immersed in a warm water bath, so that it may continue hot and fluid for several hours. At the end of this time the supernatant clear liquid is to be drawn off into congealing boxes, as will be presently explained.

The grounds, or undissolved matters in the boiler, are to be again supplied with a quantity of boiling water from an adjoining copper, and are to be once more subjected to the action of the fire, till the contents assume the appearance of dissolved jelly, and afford a fresh quantity of strong glue liquor, by the stop-cock. The grounds should be subjected a third time to this operation, after which they may be put into a bag, and squeezed in a press to leave nothing unextracted. The latter solutions are usually too weak to form glue directly, but they may be strengthened by boiling with a portion of fresh skin-parings.

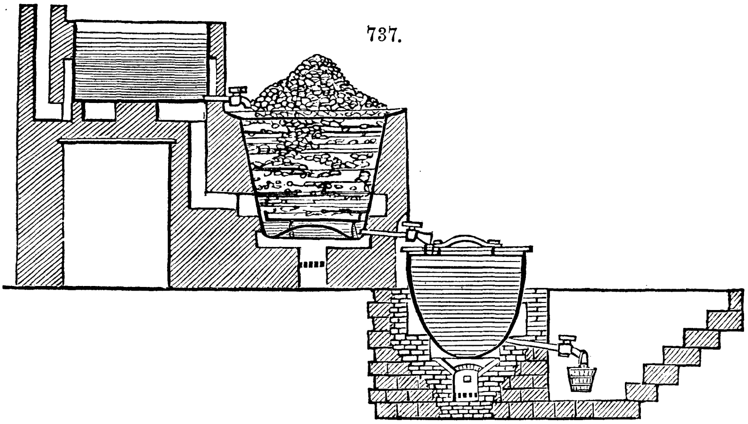
Fig. 737. represents a convenient apparatus for the boiling of skins into glue, in which there are three coppers upon three different levels; the uppermost being acted upon by the waste heat of the chimney, provides warm water in the most economical way; the second contains the crude materials, with water for dissolving them; and the third receives the solution to be settled. The last vessel is double, with water contained between the outer and inner one; and discharges its contents by a stop-cock into buckets for filling the gelatinizing wooden boxes. The last made solution has about one-five-hundredth part of alum in powder usually added to it, with proper agitation, after which it is left to settle for several hours.

The three successive boils furnish three different qualities of glue.

Flanders or Dutch glue, long much esteemed on the Continent, was made in the manner above described, but at two boils, from animal offals well washed and soaked, so as to need less boiling. The liquor being drawn off thinner, was therefore less coloured, and being made into thinner plates was very transparent. The above two boils gave two qualities of glue.

By the English practice, the whole of the animal matter is brought into solution at once, and the liquor being drawn off, hot water is poured on the residuum, and made to boil on it for some time, when the liquor thus obtained is merely used instead of water

737.



upon a fresh quantity of glue materials. The first drawn off liquor is kept hot in a settling copper for five hours, and then the clear solution is drawn off into the boxes.

These boxes are made of deal, of a square form, but a little narrower at bottom than at top. When very regular cakes of glue are wished for, cross grooves of the desired square form are cut in the bottom of the box. The liquid glue is poured into the boxes placed very level, through funnels furnished with filter cloths, till it stands at the brim of each. The apartment in which this is done ought to be as cool and dry as possible, to favour the solidification of the glue, and should be floored with stone flags kept very clean, so. that if any glue run through the seams, it may be recovered. At the end of 12 or 18 hours, or usually in the morning if the boxes have been filled over-night, the glue is sufficiently firm for the nets, and they are at this time removed to an upper story, mounted with ventilating windows to admit the air from all quarters. Here the boxes are inverted upon a moistened table, so that the gelatinous cake thus turned out will not adhere to its surface; usually the moist blade of a long knife is insinuated round the sides of the boxes beforehand, to loosen the glue. The mass is first divided into horizontal layers by a brass wire stretched in a frame, like that of a bow-saw, and guided by rulers which are placed at distances corresponding to the desired thickness of the cake of glue. The lines formed by the grooves in the bottom of the box define the superficial area of each cake, where it is to be cut with a moist knife. The gelatinous layers thus formed, must be dexterously lifted, and immediately laid upon nets stretched in wooden frames, till each frame be filled. These frames are set over each other at distances of about three inches, being supported by small wooden pegs, stuck into mortise holes in an upright, fixed round the room; so that the air may have perfectly free access on every side. The cakes must moreover be turned upside down upon the nets twice or thrice every day, which is readily managed, as each frame may be slid out like a drawer, upon the pegs at its two sides.

The drying of the glue is the most precarious part of the manufacture. The least disturbance of the weather may injure the glue during the two or three first days of its exposure; should the temperature of the air rise considerably, the gelatine may turn so soft as to become unshapely, and even to run through the meshes upon the pieces below, or it may get attached to the strings that surround them, so as not to be separable without plunging the net into boiling water. If frost supervene, the water may freeze and form numerous cracks in the cakes. Such pieces must be immediately re-melted and re-formed. A slight fog even produces upon glue newly exposed a serious deterioration; the damp condensed upon its surface occasioning a general mouldiness. A thunder-storm sometimes destroys the coagulating power in the whole laminæ at once; or causes the glue to *turn* on the nets, in the language of the manufacturer. A wind too dry or too hot may cause it to dry so quickly, as to prevent it from contracting to its proper size without numerous cracks and fissures. In this predicament, the closing of all the flaps of the windows is the only means of abating the mischief. On these accounts it is of importance to select the most temperate season of the year, such as spring and autumn, for the glue manufacture.

After the glue is dried upon the nets it may still preserve too much flexibility, or softness at least, to be saleable; in which case it must be dried in a stove by artificial heat. This aid is peculiarly requisite in a humid climate, like that of Great Britain.

When sufficiently dry it next receives a gloss, by being dipped cake by cake in ho water, and then rubbed with a brush also moistened in hot water; after which the glue is arranged upon a hurdle, and transferred to the stove room, if the weather be not sufficiently hot. One day of proper drought will make it ready for being packed up in casks.

The pale-colored, hard, and solid article, possessing a brilliant fracture, which is made from the parings of ox-hides by the first process, is the best and most cohesive, and is most suitable for joiners, cabinet-makers, painters, &c. But many workmen are influenced by such ignorant prejudices, that they still prefer a dark-colored article, with somewhat of a fetid odor, indicative of its impurity and bad preparation, the result of bad materials and too long exposure to the boiling heat.

There is a good deal of glue made in France from bones, freed from the phosphate of lime by muriatic acid. This is a poor article, possessing little cohesive force. It dissolves almost entirely in cold water, which is the best criterion of its imperfection. Glue should merely soften in cold water, and the more considerably it swells, the better, generally speaking, it is.

Some manufacturers prefer a brass to a copper pan for boiling glue, and insist much on skimming it as it boils; but the apparatus I have represented renders skimming of little consequence. For use, glue should be broken into small pieces, put along with some water into a vessel, allowed to soak for some hours, and subjected to the heat of a boiling-water bath, but not boiled itself. The surrounding hot water keeps it long in a fit state for joiners, cabinet-makers, &c.

Water containing only one hundredth part of good glue, forms a tremulous solid. When the solution, however, is heated and cooled several times, it loses the property of gelatinizing, even though it be enclosed in a vessel hermetically sealed. Isinglass or fish-glue undergoes the same change. Common glue is not soluble in alcohol, but is precipitated in a white, coherent, elastic mass, when its watery solution is treated with that fluid. By transmitting chlorine gas through a warm solution of glue a combination is very readily effected, and a viscid mass is obtained like that thrown down by alcohol. A little chlorine suffices to precipitate the whole of the glue. Concentrated sulphuric acid makes glue undergo remarkable changes; during which are produced, sugar of gelatine, leucine, an animal matter, &c. Nitric acid, with the aid of heat, converts glue into malic acid, oxalic acid, a fat analogous to suet, and into tannin; so that, in this way, one piece of skin may be made to tan another. When the mixture of glue and nitric acid is much evaporated, a detonation at last takes place. Strong acetic acid renders glue first soft and transparent, and then dissolves it. Though the solution does not gelatinize, it preserves the property of gluing surfaces together when it dries. Liquid glue dissolves a considerable quantity of lime, and also of the phosphate of lime recently precipitated. Accordingly glue is sometimes contaminated with that salt. Tannin both natural and artificial combines with glue; and with such effect, that one part of glue dissolved in 5000 parts of water affords a sensible precipitate with the infusion of nutgalls. Tannin unites with glue in several proportions, which are to each other as the numbers 1, 1½, and 2; one compound consists of 100 glue and 89 tannin; another of 100 glue and 60 tannin; and a third of 100 glue and 120 tannin. These two substances cannot be afterwards separated from each other by any known chemical process.

Glue may be freed from the foreign animal matters generally present in it, by softening it in cold water, washing it with the same several times till it no longer gives out any color, then bruising it with the hand, and suspending it in a linen bag beneath the surface of a large quantity of water at 60° F. In this case, the water loaded with the soluble impurities of the glue gradually sinks to the bottom of the vessel, while the pure glue remains in the bag surrounded with water. If this softened glue be heated to 92° without adding water, it will liquefy; and if we heat it to 122°, and filter it, some albuminous and other impurities will remain on the filter, while a colorless solution of glue will pass through.

Experiments have not yet explained how gelatine is formed from skin by ebullition. It is a change somewhat analogous to that of starch into gum and sugar, and takes place without any appreciable disengagement of gas, and even in close vessels. Gelatine, says Berzelius, does not exist in the living body, but several animal tissues, such as skin, cartilages, hartshorn, tendons, the serous membranes, and bones, are susceptible of being converted into it.

GLUTEN (*Colle Vegetale*, Fr.; *Kleber*, Germ.) was first extracted by Beccaria from wheat flour, and was long regarded as a proximate principle of plants, till Einhof, Taddei, and Berzelius succeeded in showing that it may be resolved by means of alcohol into three different substances, one of which resembles closely animal albumine, and has been called *Zymome*, or vegetable albumine; another has been called *Gliadine;* and a third, *Mucine*. The mode of separating gluten from the other constituents of wheat flour has been described towards the end of the article Bread.

Gluten, when dried in the air or a stove, diminishes greatly in size, becomes hard, brit brittle, glistening, and of a deep yellow colour. It is insoluble in ether, in fat and essential oils, and nearly so in water. Alcohol and acetic acid cause gluten to swell and make a sort of milky solution. Dilute acids and alkaline lyes dissolve gluten. Its ultimate constituents are not determined, but azote is one of them, and accordingly when moist gluten is left to ferment, it exhales the smell of old cheese.

Some years since, M. E. M. Martin, of Vervins, proposed to extract the starch without injuring the gluten, which then becomes available for alimentary purposes. His process is a mechanical one (resembling that long practised in laboratories for procuring gluten), and consists in washing wheat flour, made into a paste, with water, either by the hand or machinery.

The gluten thus obtained is susceptible of numerous useful applications for alimentary purposes. Mixed with wheat flour, in the proportions of 30 parts of flour, 10 of fresh gluten, and 7 of water, it has been employed to produce a superior sort of macaroni, vermicelli, and other kinds of Italian pastes; and MM. Véron frères, of Paris, have made with it a new sort of paste, which they have termed *granulated gluten* (*gluten granulé*).

Mr. I. P. Gentile, of the Habertonford works, near Totness, in Devonshire, has for some time past been engaged in the manufacture of gluten for alimentary purposes, and placed in the Exhibition samples of several dietetical substances made with gluten: such as macaroni, vermicelli, a sort of gluten chocolate, and a kind of meal biscuit powder.

Madame St. Etienne, the wife of Mr. Gentile's foreman, also placed in the Exhibition a very complete collection of alimentary preparations, made with gluten.

To the same category belongs Mr. Bullock's Semola, of which he has given an account in the *Lancet* of December 15, 1849, and March 9, 1850. It is, in fact, wheat gluten made into a paste with wheat flour, and granulated.

In all the above preparations, the gluten employed is that extracted from wheat by a mechanical process (hand working), as practised by M. E. M. Martin.

Messrs. Orlando Jones and Co., manufacturers of rice starch, also placed in the Exhibition a specimen of *rice gluten.* But, as it is extracted from rice by a solution of caustic soda, and precipitated from its alkaline solution by an acid, it is obvious that it must have suffered deterioration, and be less proper for alimentary purposes than gluten extracted from the grain by a mechanical process.

We hail with much satisfaction these attempts to introduce into use, as alimentary substances, preparations of gluten. No one has hitherto succeeded in making in England macaroni and vermicelli equal to the Italian pastes; for, although the English-made article presented a tolerably good appearance, it failed in cooking, either running into a mass, or falling to pieces; whereas it should simply expand and retain its form, even after long boiling. With Mr. Gentile's gluten it is to be hoped that good pastes may be made, even with English wheat. Hitherto, hundreds of tons of a most valuable and important article of food have been annually lost, and the prevention of this by the economic application of the gluten deserves, therefore, every encouragement.

By mixing gluten with wheat flour, Mr. Gentile prepares what he calls *gluten flour*, containing 42 per cent., or four times the normal quantity of gluten. This preparation is susceptible of several very useful applications. It yields a very nutritious and digestible *gluten biscuit*; mixed with cocoa it forms an agreeable and nutritious *gluten chocolate;* and mixed with beef or mutton it furnishes a highly-condensed nutritive food. Bread made with gluten flour might be advantageously employed by diabetic patients as a substitute for Bouchardat's *gluten bread.*

GLYCERINE, is a sweet substance which may be extracted from fatty substances. If we take equal parts of olive oil and finely-ground litharge, put them into a basin with a little water, set this on a sand bath moderately heated, and stir the mixture constantly, with the occasional addition of hot water to replace what is lost by evaporation, we shall obtain, in a short time, a soap or plaster of lead. After having added more water to this, we remove the vessel from the fire, decant the liquor, filter it, pass sulphuretted hydrogen through it to separate the lead, then filter afresh, and concentrate the liquor as much as possible without burning upon the sand-bath. What remains must be finally evaporated within the receiver of the air-pump. Glycerine thus prepared is a transparent liquid, without colour or smell, and of a syrupy consistence. It has a very sweet taste. Its specific gravity is 1·27 at the temperature of 60°. When thrown upon burning coals, it takes fire and burns like an oil. Water combines with it in almost all proportions; alcohol dissolves it readily; nitric acid converts it into oxalic acid; and according to Vogel, sulphuric acid transforms it into sugar, in the same way as it does starch. Ferment or yeast does not affect it in any degree.

Its constituents are, carbon 40, hydrogen 9, oxygen 51, in 100.

The employment of glycerine as an application in the treatment of deafness, and also for other purposes as a medicinal agent, has given rise to enquiries on the subject, on which account a few practical remarks may probably be interesting to some of our readers.

Glycerine is one of the products of the saponification of fat oils. It is produced in large quantities in the soap manufactories in a very impure state, being contaminated with saline and empyreumatic matters, and having a very strong disagreeable odour. In order to obtain glycerine from this source, the residuary liquors are evaporated and treated with alcohol, which dissolves out the glycerine. The alcohol having been separated by evaporation, the glycerine is diluted with water, and boiled with animal charcoal. This process must be repeated several times, or until the result is sufficiently free from smell. It is, however, extremely difficult to obtain pure glycerine from this source, on account of the nature and condition of the ingredients usually employed in making soap, which it is almost impossible to deprive of rancid odour.

The best method of obtaining glycerine for medicinal purposes is to evaporate the water used in making emplastrum plumbi. When the oil employed is fresh, and the process is carefully conducted, the result is easily made fit for use, and is almost without odour. Any lead with which it may be contaminated is separated by passing a stream of sulphuretted hydrogen through it when in a dilute state. The excess of gas escapes during the process of evaporation. If requisite, it may be boiled with animal charcoal, filtered, and evaporated. The specific gravity, when reduced to the proper consistence, is 1·27.

It is now about twelve months since an announcement appeared in the medical journals, respecting a new cure for deafness, discovered by Mr. Yearsley. The remedy was reported to be perfectly simple, remarkably safe and very effectual. Several papers by Mr. Yearsley appeared in the *Lancet* during July and August, 1848; and from the statements therein contained, it appeared that the novelty consisted in the insertion of a piece of moistened cotton wool into the ear in a particular manner. In answer to the intimation that he "had not so fully described the *modus operandi* as to enable others to adopt it with more than a mere chance of success," Mr. Yearsley observes "in answer, I have only to say, that the experience of several years has taught me that it is impossible to convey to others, in words, such explicit directions as shall enable them to manipulate with any degree of certainty. In fact, it was on this account that I have so long held back from publishing any account of the remarkable fact I had observed in my practice."

GNEISS, is the name of one of the great mountain formations, being reckoned the oldest of the stratified rocks. It is composed of the same substances as granite, viz. quartz, mica, and felspar. In gneiss, however, they are not in granular crystals, but in scales, so as to give the mass a slaty structure. It abounds in metallic treasures.

GOLD. (Eng. and Germ.; *Or*, Fr.) This metal is distinguished by its splendid yellow colour; its great density = 19·3 compared to water 1·0; its fusibility at the 32d degree of Wedgewood's pyrometer; its pre-eminent ductility and malleability, whence it can be beat into leaves only 1-282,000th of an inch thick; and its insolubility in any acid menstruum, except the mixture of muriatic and nitric acids, styled by the alchemists *aqua regia*, because gold was deemed by them to be the king of metals.

Gold is found only in the metallic state, sometimes crystallized in the cube, and its derivative forms. It occurs also in threads of various sizes, twisted and interlaced into a chain of minute octahedral crystals; as also in spangles or roundish grains, which when of a certain magnitude are called *pepitas*. The small grains are not fragments broken from a greater mass; but they show by their flattened ovoid shape and their rounded outline that this is their original state. The spec. grav. of native gold varies from 13·3 to 17·7. Humboldt states that the largest *pepita* known was one found in Peru weighing about 12 kilogrammes (26½ lbs. avoird.); but masses have been quoted in the province of Quito which weighed nearly four times as much.

Another ore of gold is the alloy with silver, or argental gold, the electrum of Pliny, so called from its amber shade. It seems to be a definite compound, containing in 100 parts, 64 of gold and 36 of silver.

The mineral formations in which this metal occurs are the crystalline primitive rocks, the compact transition rocks, the trachytic and trap rocks, and alluvial grounds.

It never predominates to such a degree as to constitute veins by itself. It is either disseminated, and as it were impasted in stony masses, or spread out in thin plates or grains on their surface, or, lastly, implanted in their cavities, under the shape of filaments or crystallized twigs. The minerals composing the veins are either quartz, calc-spar, or sulphate of baryta. The ores that accompany the gold in these veins are chiefly iron pyrites, copper pyrites, galena, blende, and mispickel (arsenical pyrites).

In the ores called auriferous pyrites, this metal occurs either in a visible or invisible form, and though invisible in the fresh pyrites becomes visible by its decomposition; as the hydrated oxide of iron allows the native gold particles to shine forth on their reddish-

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brown ground, even when the precious metal may constitute only the five millionth part of its weight, as at Rammelsberg in the Hartz. In that state it has been extracted with profit; most frequently by amalgamation with mercury, proving that the gold was in the native state, and not in that of a sulphuret.

Gold exists among the primitive strata, disseminated in small grains, spangles, and crystals. Brazil affords a remarkable example of this species of gold mine. Beds of granular quartz, or micaceous specular iron, in the Sierra of Cocäes, 12 leagues beyond Villa Rica, which form a portion of a mica-slate district, include a great quantity of native gold in spangles, which in this ferruginous rock replace mica.

Gold has never been observed in any secondary formation, but pretty abundantly in its true and primary locality among the trap rocks of igneous origin; implanted on the sides of the fissures, or disseminated in the veins.

The auriferous ores of Hungary and Transylvania, composed of tellurium, silver pyrites or sulphuret of silver, and native gold, lie in masses or powerful veins in a rock of trachyte, or in a decomposed feldspar subordinate to it. Such is the locality of the gold ore of Königsberg, of Telkebanya, between Eperies and Tokay in Hungary, and probably that of the gold ores of Kapnick, Felsobanya, &c., in Transylvania; an arrangemenent nearly the same with what occurs in Equatorial America. The auriferous veins of Guanaxuato, of Real del Monte, of Villalpando, are similar to those of Schemnitz in Hungary, as to magnitude, relative position, the nature of the ores they include, and of the rocks they traverse. These districts have impressed all mineralogists with the evidences of the action of volcanic fire. Breislak and Hacquet have described the gold mines of Transylvania as situated in the crater of an ancient volcano. It is certain that the trachytes which form the principal portions of the rocks including gold, are now almost universally regarded as of igneous or volcanic origin.

It would seem, however, that the primary source of the gold is not in these rocks, but rather in the sienites and greenstone porphyries below them, which in Hungary and Transylvania are rich in great auriferous deposites; for gold has never been found in the trachyte of the Euganean mountains, of the mountains of the Vicentin, of those of Auvergne; all of which are superposed upon granite rocks, barren in metal.

Finally, if it be true that the ancients worked mines of gold in the island of Ischia, it would be another example, and a very remarkable one, of the presence of this metal in trachytes of an origin evidently volcanic.

Gold is, however, much more common in the alluvial grounds than among the primitive and pyrogenous rocks just described. It is found disseminated under the form of spangles, in the silicious, argillaceous, and ferruginous sands of certain plains and rivers, especially in their re-entering angles, at the season of low water, and after storms and temporary floods.

It has been supposed that the gold found in the beds of rivers had been torn out by the waters from the veins and primitive rocks, which they traverse. Some have even searched, but in vain, at the source of auriferous streams, for the native bed of this precious metal. The gold in them belongs, however, to the grounds washed by the waters as they glide along. This opinion, suggested at first by Delius, and supported by Deborn, Guettard, Robitant, Balbo, &c., is founded upon just observations. 1. The soil of these plains contains, frequently, at a certain depth and in several spots, spangles of gold, separable by washing. 2. The beds of the auriferous rivers and streamlets contain more gold after storms of rain upon the plains than in any other circumstances. 3. It happens almost always that gold is found among the sands of rivers only in a very circumscribed space; on ascending these rivers their sands cease to afford gold; though did this metal come from the rocks above, it should be found more abundantly near the source of the rivers. Thus it is known that the Orco contains no gold except from Pont to its junction with the Po. The Ticino affords gold only below the Lago Maggiore, and consequently far from the primitive mountains, after traversing a lake, where its course is slackened, and into which whatsoever it carried down from these mountains must have been deposited. The Rhine gives more gold near Strasburg than near Basle, though the latter be much closer to the mountains. The sands of the Danube do not contain a grain of gold, while this river runs in a mountainous region; that is, from the frontiers of the bishopric of Passau to Efferding; but its sands become auriferous in the plains below. The same thing is true of the Ems; the sands of the upper portion of this river, as it flows among the mountains of Styria, include no gold; but from its entrance into the plain at Steyer, till its embouchure in the Danube, its sands become auriferous, and are even rich enough to be washed with profit.

The greater part of the auriferous sands, in Europe, Asia, Africa, and America, are black or red, and consequently ferruginous; a remarkable circumstance in the geological position of alluvial gold. M. Napione supposes that the gold of these ferruginous grounds is due to the decomposition of auriferous pyrites. The auriferous sand occurring in Hungary almost always in the neighborhood of the beds of *lignites*, and the petrified wood covered with gold grains, found buried at a depth of 55 yards in clay, in the mine of Vorospatak near Abrabanya in Transylvania, might lead us to presume that the epoch of the formation of the auriferous alluvia is not remote from that of the lignites. The same association of gold ore and fossil wood occurs in South America, at Moco. Near the village of Lloro, have been discovered at a depth of 20 feet, large trunks of petrified trees, surrounded with fragments of trap rocks interspersed with spangles of gold and platinum. But the alluvial soil affords likewise all the characters of the basaltic rocks; thus in France, the Cèze and the Gardon, auriferous rivers, where they afford most gold, flow over ground apparently derived from the destruction of the trap rocks, which occur *in situ* higher up the country. This fact had struck Reaumur, and this celebrated observer had remarked that the sand which more immediately accompanies the gold spangles in most rivers, and particularly in the Rhone and the Rhine, is composed, like that of Ceylon and Expailly, of black protoxyde of iron and small grains of rubies, corindon, hyacinth, &c. Titanium has been observed more recently. It has, lastly, been remarked that the gold of alluvial formations is purer than that extracted from rocks.

Principal Gold Mines.

Spain anciently possessed mines of gold in regular veins, especially in the province of Asturias; but the richness of the American mines has made them to be neglected. The Tagus, and some other streams of that country, were said to roll over golden sands. France contains no workable gold mines; but it presents in several of its rivers auriferous sands. There are some gold mines in Piedmont; particularly the veins of auriferous pyrites of Macugnagna, at the foot of Monte Rosa, lying in a mountain of gneiss; and although they do not contain 10 or 11 grains of gold in a hundred weight, they have long defrayed the expense of working them. On the southern slope of the Pennine Alps, from the Simplon and Monte Rosa to the valley of Aoste, several auriferous districts and rivers occur. Such are the torrent Evenson, which has afforded much gold by washing; the Orco, in its passage from the Pont to the Po; the reddish grounds over which this little river runs for several miles, and the hills in the neighborhood of Chivasso, contain gold spangles in considerable quantity.

In the county of Wicklow, in Ireland, a quartzose and ferruginous sand was discovered not long ago, containing many particles of gold, with *pepitas* or solid pieces, one of which weighed 22 ounces. No less than 1000 ounces of gold were collected.

There are auriferous sands in some rivers of Switzerland, as the Reuss and the Aar. In Germany no mine of gold is worked, except in the territory of Salzburg, amid the chain of mountains which separates the Tyrol and Carinthia.

The mines of Hungary and Transylvania are the only gold mines of any importance in Europe; they are remarkable for their position, the peculiar metals that accompany them, and their product, estimated at about 1430 pounds avoird. annually. The principal ones are in Hungary. 1. Those of Konigsberg. The native gold is disseminated in ores of sulphuret of silver, which occur in small masses and in veins in a decomposing feldspar rock, amid a conglomerate of pumice, constituting a portion of the trachytic formation. 2. Those of Borson, Schemnitz. And, 3. of Felsobanya; ores also of auriferous sulphuret of silver, occur in veins of sienite and greenstone porphyry. 4. Those of Telkebanya, to the south of Kaschau, are in a deposite of auriferous pyrites amid trap rocks of the most recent formation.

In Transylvania the gold mines occur in veins often of great magnitude, 6, 8, and sometimes 40 yards thick. These veins have no side plates or wall stones, but abut without intermediate gangues at the primitive rock. They consist of carious quartz, ferriferous limestone, heavy spar, fluor spar, and sulphuret of silver. The mine of Kapnik deserves notice, where the gold is associated with orpiment, and that of Vcrospatak in granite rocks; those of Offenbanya, Zalatna, and Nagy-Ag, where it is associated with tellurium The last is in a sienitic rock on the limits of the trachyte.

In Sweden, the mine of Edelfors in Smoland may be mentioned, where the gold occurs native and in auriferous pyrites; the veins are a brown quartz, in a mountain of foliated hornstone.

In Siberia, native gold occurs in a hornstone at Schlangenberg or Zmeof, and at Zmeino-garsk in the Altai mountains, accompanied with many other ores.

The gold mine of Berezof in the Oural mountains has been long known, consisting of *partially decomposed auriferous pyrites*, disseminated in a vein of greasy quartz. About 1820, a very rich deposit of native gold was discovered on the eastern side of the Oural mountains, disseminated at some yards depth in an argillaceous loam, and accompanied with the *debris* of rocks which usually compose the auriferous alluvial soils, as greenstone, serpentine, protoxide of iron, corundum, &c. The rivers of this district possess auriferous sands. The product of the gold mines of the Oural, in 1845, was 11,808 pounds avoirdupois, and in 1846, 11,327 pounds; that of Siberia, in 1845, 37,576 pounds, and in 1846, 48,863 pounds. In these accounts the pood has been reckoned at 36 lbs. It is believed that in 1847 and 1849 the yield was still larger, but it must since have materially fallen off, as it is stated in *Erman's Archives* that the yield in 1851 will not exceed 20,000 pounds troy.

In Asia, and especially in its southern districts, there are many mines, streams, rivers, and wastes, which contain this metal. The Pactolus, a small river of Lydia, rolled over such golden sands, that it was supposed to constitute the origin of the wealth of Crœsus. But these deposits are now poor and forgotten. Japan, Formosa, Ceylon, Java, Sumatra, Borneo, the Philippines, and some other islands of the Indian Archipelago, are rich in gold mines. Those of Borneo are worked by the Chinese in an alluvial soil on the western coast, at the foot of a chain of volcanic mountains.

Little or no gold comes into Europe from Asia, because its servile inhabitants place their fortune in treasure, and love to hoard up that precious metal.

Numerous gold mines occur on the two slopes of the chain of the Cailas mountains in the Oundès, a province of Little Thibet. The gold lies in quartz veins which traverse a very crumbling reddish granite.

Africa was, with Spain, the source of the greater portion of the gold possessed by the ancients. The gold which Africa still brings into the market is always in dust, showing that the metal is obtained by washing the alluvial soils. None of it is collected in the north of that continent; three or four districts only are remarkable for the quantity of gold they produce.

The first mines are those of Kordofan, between Darfour and Abyssinia. The negroes transport the gold in quills of the ostrich or vulture. These mines seem to have been known to the ancients, who considered Ethiopia to abound in gold. Herodotus relates that the king of that country exhibited to the ambassadors of Cambyses all their prisoners bound with golden chains.

The second and chief exploitation of gold dust is to the south of the great desert of Zaara, in the western part of Africa, from the mouth of the Senegal to the Cape of Palms. The gold occurs in spangles, chiefly near the surface of the earth, in the bed of rivulets, and always in a ferruginous earth. In some places the negroes dig wells in the soil to a depth of about 40 feet, unsupported by any props. They do not follow any vein; nor do they construct a gallery. By repeated washings they separate the gold from the earthy matters.

The same district furnishes also the greater part of what is carried to Morocco Fez, and Algiers, by the caravans which go from Timbuctoo on the Niger, across the great desert of Zaara. The gold which arrives by Sennaar at Cairo and Alexandria comes from the same quarter. From Mungo Park's description, it appears that the gold spangles are found usually in a ferruginous small gravel, buried under rolled pebbles.

The third spot in Africa where gold is collected is on the south-east coast, between the twenty-fifth and the twenty-second degree of south latitude, opposite to Madagascar, in the country of Sofala. Some persons think that this was the kingdom of Ophir, whence Solomon obtained his gold.

In modern times, the richest gold mines are found in South America. It occurs there principally in spangles among the alluvial earths, and in the beds of rivers; more rarely in veins. See *California, infra.*

There is little gold in the northern part of America. In 1810, a mass of alluvial gold, weighing 28 pounds, was found in the gravel pits of the creeks of Rockhole, district of Lebanon, in North Carolina.

Previously to the important discoveries in California, Brazil, Choco, and Chili, were the regions which furnished most gold. The only contributor of Chilian objects to the Great Exhibition was one who forwarded a lump of gold ore weighing 3 cwt., which was brought up from a deep mine on the back of a miner, from a depth of 45 yards beneath the surface.

The gold of Mexico is in a great measure contained in the argentiferous veins, so numerous in that country, whose principal localities are mentioned under the article SILVER. The silver of the argentiferous ores of Guanaxuato contains one 360th of its weight of gold; the annual product of the mines being valued at from 2640 to 3300 pounds avoirdupois.

Oaxaco contains the only auriferous veins exploited as gold mines in Mexico; they traverse the rocks of gneiss and mica slate.

All the rivers of the province of Caracas, to ten degrees north of the line, flow over golden sands.

Peru is not rich in gold ores. In the provinces of Huailas and Pataz, this metal is mined in veins of greasy quartz, variegated with red ferruginous spots, which traverse primitive rocks. The mines called *pacos de oro*, consist of ores of iron and copper oxides, containing a great quantity of gold

All the gold furnished by New Grenada (New Columbia) is the product of washings established in alluvial grounds. The gold exists in spangles and in grains, disseminated among fragments of greenstone and porphyry. At Choco, along with the gold and platinum, hyacinths, zircons, and titanium occur. There has been found, as already stated, in the auriferous localities, large trunks of petrified trees. The gold of Antioquia is 20 carats fine, that of Choco 21, and the largest lump or *pepita* of gold weighed about 27½ pounds avoirdupois. The gold of Chili also occurs in alluvial formations.

Brazil does not contain any gold mine, properly so called; for the veins containing the metal are seldom worked.

It is in the sands of the Mandi, a branch of the Rio-Dolce, at Catapreta, that the auriferous ferruginous sands were first discovered in 1682. Since then they have been found almost everywhere at the foot of the immense chain of mountains, which runs nearly parallel with the coast, from the 5th degree south to the 30th. It is particularly near Villa Rica, in the environs of the village Cocäes, that the numerous washings for gold are established. The *pepitas* occur in different forms, often adhering to micaceous specular iron. But in the province of Minas Geräes, the gold occurs also in veins, in beds, and in grains, disseminated among the alluvial loams. It has been estimated in annual product, by several authors, at about 2800 pounds avoirdupois of fine metal.

We thus see that almost all the gold brought into the market comes from alluvial lands, and is extracted by washing.

The gold coin of the ancients was made chiefly out of alluvial gold, for in these early times the metallurgic arts were not sufficiently advanced to enable them to purify it. The gold dust from Bambouk in Africa is of 22¼ carats fine, and some from Morocco is even 23.

The gold of Giron, in New Grenada, is of 23¾ carats; being the purest from America. "For those who traffick in gold," says Humboldt, "it is sufficient to learn the place where the metal has been collected, to know its title."

Californian Gold Mines.—The accident which first revealed the golden treasures of the soil of California is thus related by a writer of Article VII. of the Quarterly Review, for September, 1852. Captain Suter, the first white man who had established himself in the district where the Americanos joins the Sacramento, having erected a saw-mill on the former river, whose tail race turned out to be too narrow, took out the wheel, and let the water run freely off. A great body of earth having been carried away by the torrent, laid bare many shining yellow spangles, and on examination, Mr. Marshall, his surveyor, picked up several little lumps of gold. He and Captain Suter then commenced a search together and gathered an ounce of the ore from the sand without any difficulty; and with his knife the captain picked out a lump of an ounce and a half from the rock. A Kentuckian workman employed at the mill had espied their supposed secret discovery, and when after a short absence the gentlemen returned, he showed them a handful of the glittering dust. The captain hired a gang of fifty Indians, and set them to work. The news spread, but the announcement of the discovery was received with incredulity beyond the immediate neighbourhood. But presently when large and continuous imports of gold from San Francisco placed the matter beyond doubt, there ensued such a stir in the States, as even in that go-a-head region is wholly without parallel: numbers of every age and of every variety of occupation pushed for the land of promise. Many were accompanied by their families, and most under the excitement of the hour overlooked their physical unfitness, and their inability to procure necessaries. The waters of the Humboldt, from their head to their "sink," a space of nearly 300 miles, are in the dry season strongly impregnated with alkali: and it was here that they first began to faint. Some died from thirst, others from ague, others fell beneath the burdens they attempted to carry when their last animal dropped into the putrid marsh, which grew thicker at every step. Beyond the "sink" the diminished bands had to encounter sixty or seventy miles of desert, where not a blade of herbage grew, and not a drop of pure water could be procured; and those who pushed safely through this ordeal had still to ascend the icy slopes of Sierra Nevada, when the rigours of winter were added to all other difficulties. At different points, one being almost in sight of the golden land, overwearied groups had formed encampments, in case perhaps some help might reach them. It is to the credit of the settlers that on hearing this, they strained their resources to the utmost to afford relief. Yet when all was done, a sick, destitute, most wretched horde of stragglers, was all that remained of the multitude, who, full of hope and spirits, had commenced the prairie journey.

Enterprise and energy have now overcome or smoothed the worst difficulties of the route. A great central railroad has been projected, and will probably at no distant time be formed.

To this time, the stream of life flowing into California has kept continually increasing. Upwards of 20,000 souls, and about 50,000 animals, forming a scattered train of about 700 miles in length, passed Fort Kearney in the month of May last. In this multitude

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the strangest contrasts were seen; ladies on spirited steeds, in full Bloomer costume, or in the more modest equestrian habit to which we are accustomed, and men gallantly mounted with Kossuth hat and plume, swept by the humble pedlar driving ass or mule, and toil-worn women, leading their children by the hand. Some had their little stock of provisions strapped on their backs; others trusted to hand-carts and wheelbarrows.

"The journey would be pleasant," writes one of the company, "but for the vast number of graves along the road. There are about 80 graves to 100 miles so far; that is new ones, the old ones are nearly obliterated, and their places no longer known by man." This passage depicts well the recklessness with which in the States life is squandered in the pursuit of gain. By sea, the arrivals are even more numerous; upwards of 10,000 landed at the port of San Francisco in May, and about an equal number in June. In the first six months of the year 10,000 Chinamen had arrived to claim part in the golden harvest; 400 more followed in the first fortnight of July, and eighteen women, in the costume of the Celestial Empire, had come infrom Hong Kong. The population of California was about 200,000 at the commencement of the present year; it will be 300,000 by its close. Already the sea-board of California is brought within a month's passage of England; and its exports now amount in value to one fourth the exports of the United Kingdom. The produce of California up to the 10th of January, 1851, is stated by Mr. Scheer at about 62 millions sterling; but these figures taken from a gold circular published at San Francisco must be much too high. From 35 to 40 millions would probably be nearer the mark. 17,339,544*l.* is the amount for last year, as carefully computed by Mr. Birkmyre. See *Times*, May 21. The exports this year are known to have been during the three first months, 3,900,000 dollars more than those of the three corresponding months of the preceding year, 1851.

Report of Deposits of Gold from California, at the several United States Mints,

	dollars.
in 1848	44,177
1849	6,147,509
1850	36,074,062
1851	55,938,232

Hussey & Co.'s Circular, San Francisco, July 30, 1852.

Australian Gold Mines.—The discovery of a great gold field in Australia to the westward of Bathurst, about 150 miles from Sydney, was officially made known in Great Britain, by a despatch from Sir C. A. Fitzroy to Earl Grey, on the 18th September, 1851, many persons with a tin dish having obtained from one to two ounces per day. On the 25th of May, he writes that lumps have been obtained varying in weight from an ounce to four pounds. On the 29th May, he writes that gold has been found in abundance, that people of every class are proceeding to the locality, that the field is rich, and from the geological formation of the country of immense area. By assay the gold was found to consist of 91.1 of that metal and about 8.333 of silver, with a little base metal; or of 22 carats in fineness. July 17th, a mass of gold weighing 106 pounds was found imbedded in the quartz matrix, about 53 miles from Bathurst; and much more, justifying the anticipations formed of the vast richness and extent of the gold field in this colony. This magnificent treasure, the property of Dr. Kerr, surpasses the largest mass found in California, which was 28 pounds; and that in Russia, which was 70 pounds, now in the museum at Petersburg. One party of six persons got at the same time 400*l.* in ten days, by means of a quicksilver machine; and a party of three, who were unsuccessful for seven days, obtained in five days more, 200 ounces. A royalty of 10 per cent. was ordered to be paid on gold in matrix if found in Crown lands, and 5 per cent. if found in private property. Four armed men travel in the carriage that conveys the gold from the diggings to Sydney, accompanied by two armed constables, in general weekly, or oftener if required. The licence fee is 30*s.* a month. August 19th, 1851, the Governor Sir C. Fitzroy reports to Earl Grey, that gold to the value of 70,000*l.* had been already collected; and on the 21st, that 3,614 ozs. had that morning arrived at Sydney from Bathurst, worth upwards of 12,600*l.*

August 25th, 1851, Lieutenant Governor C. J. Latrobe announced to Earl Grey from Melbourne, the discovery of large deposits of gold in that district of the colony. In a second Parliamentary blue book, issued February 3, 1852, it is stated that 79,340 ounces of gold, worth 257,855*l.* 7*s.* had been previously forwarded to England; and that the gold fields of the colony of Victoria rival, if they do not exceed in value, the first discovered gold fields of New South Wales; the total value being now 300,000*l.*; and a little time afterwards about half a million sterling. Mr. E. Hargraves, commissioner for Crown lands, announces from Bathurst, that no part of California which he had seen has produced gold so generally and to such an extent as Summerhill Creek, the Turon

River and its tributaries. A letter from Sir J. F. W. Herschel, Bart., dated Royal Mint, London, February 7th, 1852, says, "it is believed that in California, gold to the value of 18 millions sterling had been found during each of the two last years; and prior to the discovery of that gold region, the whole annual produce throughout the world was supposed to be only about one-fifth of that amount.

Taking the actual amount shipped from Melbourne to the end of March last, and allowing for the quantity supposed to be at the diggings, and waiting shipment, it would appear that about 700,000 ounces had been raised in Victoria. At 3*l.* per oz. this would be worth 2,100,000*l.* The licences up to the same date were 49,386; equivalent to 42*l.* 10*s.* as the average monthly earnings of each licensed digger. The amount raised in New South Wales to the end of March may be taken at 320,000 ounces, and the value at 960,000*l.*; being at the rate of 31*l.* 3*s.* monthly per individual; probably about 1*l.* daily for each digger. Australia will soon be supplied with silver coin. The shipments on board (September 13) are understood to amount to 2,000,000*l.* and estimating the additional sum taken out by emigrants, it is probable that the value of the total quantity exported equals that of the gold received. The diggers must be largely benefited by these shipments of coin, as the gold, which in London would realize 4*l.* per oz., has not always brought them 3*l.* The gold fields discovered in Australia stretch over 1000 miles, in a south-westerly direction from Moreton district to Ballarat.

Up to the first week in June last, it is certain from the actual exports, that the total gold raised in Australia must have amounted in value to 4,000,000*l.* sterling; and the produce was still on the increase. The number of diggers at present hardly reaches 20,000. It seems moderate to assume that 50,000 labourers will be scattered over the Australian gold fields before the end of the present year; and taking their earnings at only 20*l.* per month, we shall have a yield then of 12,000,000*l.* yearly.

Mr. Birkmyre supposes that in 1846 there were raised from,—

	£
North and South America	1,301,500
Russia	3,414,427
Austria	282,750
Piedmont, Spain, and North Germany	20,696
Africa	203,900
Borneo	305,900
Ava, Malacca and other countries	317,519
	£ 5,846 692

This total is exclusive of China and Japan.

Metallurgic treatment of gold.—The gold found in the sands of rivers, or in auriferous soils, needs not be subjected to any metallurgic process, properly speaking. The Orpaillers separate it from the sands, by washing them first upon inclined tables, sometimes covered with a cloth, and then by hand in wooden bowls of a particular form. Amalgamation is employed to carry off from the sand the minuter particles of gold they may contain. The people called Bohemians, Cigans, or Tehinganes, who wash the auriferous sands in Hungary, employ a plank with 24 transverse grooves cut in its surface. They hold this plank in an inclined position, and put the sand to be washed in the first groove; they then throw water on it, when the gold mixed with a little sand collects usually towards the lowest furrow. They remove this mixture into a flat wooden basin, and by a peculiar sleight of hand, separate the gold entirely from the sand. The richest of the auriferous ores consist of the native gold quite visible, disseminated in a gangue, but the veins are seldom continuous for any length. The other ores are auriferous metallic sulphurets, such as sulphurets of copper, silver, arsenic, &c., and particularly iron.

The stony ores are first ground in the stamping mill, and then washed in hand-basins, or on wooden tables.

The auriferous sulphurets are much more common, but much poorer than the former ores; some contain only one 200,000th part of gold, and yet they may be worked with advantage, when treated with skill and economy.

The gold of these ores is separated by two different processes; namely, by fusion and amalgamation.

The auriferous metallic sulphurets are first roasted; then melted into *mattes*, which are roasted anew; next fused with lead, whence an auriferous lead is obtained, which may be refined by the process of cupellation.

When the gold ores are very rich, they are melted directly with lead, without preliminary calcination or fusion. These processes are, however, little practised, because they are less economical and certain than amalgamation, especially when the gold ores are very poor.

If these ores consist of copper pyrites, and if their treatment has been pushed to the point

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of obtaining auriferous rose copper, or even black copper including gold, the precious metal cannot be separated by the process of liquation, because the gold, having more affinity for copper than for lead, can be but partially run off by the latter metal. For these reasons the process of amalgamation is far preferable.

This process being the same for silver, I shall reserve its description for this metal. The rich ores in which the native gold is apparent, and merely disseminated in a stony gangue, are directly triturated with quicksilver, without any preparatory operation. As to the poor ores, in which the gold seems lost amid a great mass of iron, sulphuret of copper, &c., they are subjected to a roasting before being amalgamated. This process seems requisite to lay bare the gold enveloped in the sulphurets. The quicksilver with which the ore is now ground, seizes the whole of its gold, in however small quantity this metal may be present.

The gold procured by the refining process with lead, is free from copper and lead, but it may contain iron, tin, or silver. It cannot be separated from iron and tin without great difficulty and expense, if the proportion of gold be too small to admit of the employment of muriatic acid.

By cupellation with lead, gold may be deprived of any antimony united with it.

Tin gives gold a remarkable hardness and brittleness; a piece of gold, exposed for some time over a bath of red hot tin, becomes brittle. The same thing happens more readily over antimony, from the volatility of this metal. A two thousandth part of antimony, bismuth, or lead, destroys the ductility of gold. The tin may be got rid of by throwing some corrosive sublimate or nitre into a crucible, containing the melted alloy. By the first agent, perchloride of tin is volatilized; by the second, *stannate* of potash forms, which is carried off in the resulting alkaline scoriæ.

Gold treated by the process of amalgamation, contains commonly nothing but a little silver. The silver is dissolved out by nitric acid, which leaves the gold untouched; but to make this *parting* with success and economy on the great scale, several precautions must be observed.

If the gold do not contain fully two thirds of its weight of silver, this metal, being thoroughly enveloped by the gold, is partially screened from the action of the acid. Whenever, therefore, it is known by a trial on a small scale, that the silver is much below this proportion, we must bring the alloy of gold and silver to that standard by adding the requisite quantity of the latter metal. This process is called quartation.

This alloy is then granulated or laminated; and from twice to thrice its weight of sulphuric or nitric acid is to be boiled upon it; and when it is judged that the solution has been pushed as far as possible by this first acid, it is decanted, and new acid is poured on. Lastly, after having washed the gold, some sulphuric acid is to be boiled over it, which carries off a two or three thousandth part of silver, which nitric acid alone could not dissolve. Thus perfectly pure gold is obtained.

The silver held in solution by the sulphuric or nitric acid is precipitated in the metallic state by copper, or in the state of chloride by sea-salt. See Parting.

Not only has the ratio between the value of gold and silver varied much in different ages of the world; but the ratio between these metals and the commodities they represent has undergone variations, owing to the circumstances in which their mines have been successively placed; since they have always poured a greater quantity of the metals into the market than has been absorbed by use. This quantity has greatly increased since the discovery of America, a period of little more than 300 years. The mines of that continent, rich, numerous, and easily worked, by augmenting the mass of gold and silver, necessarily lessened the value of these metals compared with that of the objects of commerce represented by them, so that everything else being equal, there is now required for purchasing the same quantity of commodities, much more gold or silver than was necessary in the reign of Henry VII., before the discovery of America. This productiveness of the American mines has had an influence on those of the ancient continent; many of whose silver and gold mines have been abandoned, not because the veins or auriferous sands are less rich than they were, but because their product no longer represents the value of human labor, and of the goods to be furnished in return for their exploitation.

In the 3d vol. of the Mining Journal, p. 331, we have the following statement as to the produce of the precious metals.—" In 40 years, from 1790 to 1830, Mexico produced 6,436,453*l.* worth of gold, and 139,818,032*l.* of silver. Chili, 2,768,488*l.* of gold, and 1,822,924*l.* of silver. Buenos Ayres, 4,024,895*l.* of gold, and 27,182,673*l.* of silver. Russia, 3,703,743*l.* of gold, and 1,502,981*l.* of silver. Total, 1880 millions sterling, or 47 millions per annum.

The following table shows what proportion the product of the mines of America bears to that of the mines of the ancient continent.

***Table** of the Quantities of Gold which may be considered as having been brought into the European Market, every Year on an Average, from* 1790 *to* 1802.

Continents.	Gold.
ANCIENT CONTINENT.	lbs. Avoir.
Asia:	
Siberia	3740
Africa	3300
Europe:	
Hungary	1430
Salzbourg	165
Austrian States	165
Hartz and Hessia	
Saxony	
Norway	
Sweden	
France	
Spain, &c.	
Total of the Ancient Continent	8800
NEW CONTINENT.	
North America	2860
South America	
Spanish dominions	22,000
Brazil	15,400
Total of the New Continent	40,260

The mines of America have sent into Europe three and a half times more gold, and twelve times more silver, than those of the ancient continent. The total quantity of silver was to that of gold in the ratio of 55 to 1; a very different ratio from that which holds really in the value of these two metals, which is in Europe as 1 to 15. This difference depends upon several causes, which cannot be investigated here at length; but it may be stated that gold, by its rarity and price, being much less employed in the arts than silver, the demand for it is also much less; and this cause is sufficient to lower its price much beneath what it would have been, if it had followed the ratio of its quantity compared to that of silver. Thus also bismuth, tin, &c., though much rarer than silver, are, nevertheless, very inferior in price to it. Before the discovery of America, the value of gold was not so distant from that of silver, because since that era silver has been distributed in Europe in a far greater proportion than gold. In Asia the proportion is now actually only 1 to 11 or 12; the product of the gold mines in that quarter, being not so much below that of the silver mines as in the rest of the world.

The total annual production of Gold at present has been estimated as follows.

From the ancient Spanish colonies of America	10,400 kilogrammes
Brazil	600
Europe and Asiatic Russia	6,200
The Indian Archipelago	4,700
Africa	14,000 ?
	35,900=36 tons nearly

without taking into account the quantity of gold now extracted from silver.

Gold has less affinity for oxygen than any other metal. When alone, it cannot be oxydized by any degree of heat with contact of air, although in combination with other oxydized bodies, it may pass into the state of an oxyde, and be even vitrified. The purple smoke into which gold leaf is converted by an electric discharge is not an oxyde, for it is equally formed when the discharge is made through it in hydrogen gas. There are two oxydes of gold; the first or protoxyde is a green powder, which may be obtained by pouring, in the cold, a solution of potash into a solution of the metallic chloride. It is not durable, but soon changes in the menstruum into metallic gold, and peroxyde. Its constituents are 96·13 metal, and 3·87 oxygen. The peroxyde is best prepared by adding magnesia to a solution of the metallic chloride; washing the precipitate with water till this no longer takes a yellow tint from muriatic acid; then digesting strong nitric acid upon the residuum, which removes the magnesia, and leaves the peroxyde in the form of a black or dark brown powder, which seems to partake more of the properties of a metallic acid than a base. It contains 10·77 per cent. of oxygen. For the curious combination of gold and tin, called the PURPLE PRECIPITATE OF CASSIUS, see this article, and PIGMENTS VITRIFIABLE.

Gold beating.—This is the art of reducing gold to extremely thin leaves, by beating with a hammer. The processes employed for this purpose may be applied to other metals, as silver, platinum, and copper. Under tin, zinc, &c., we shall mention such modifications of the processes as these metals require to reduce them to thin leaves. The Romans used to gild the ceilings and walls of their apartments; and Pliny tells us, that from an ounce of gold forming a plate of 4 fingers square, about 600 leaves of the same area were hammered. At the present day, a piece of gold is extended so as to cover a space 651,590 times greater than its primary surface when cast.

The gold employed in this art ought to be of the finest standard. Alloy hardens gold, and renders it less malleable; so that the fraudulent tradesman who should attempt to debase the gold, would expose himself to much greater loss in the operations, than he could derive of profit from the alloy.

Four principal operations constitute the art of gold beating. 1. The casting of the gold ingots. 2. The hammering. 3. The lamination; and 4, the beating.

1. The gold is melted in a crucible along with a little borax. When it has become liquid enough, it is poured out into the ingot-moulds previously heated, and greased on the inside. The ingot is taken out and annealed in hot ashes, which both soften it and free it from grease. The moulds are made of cast iron, with a somewhat concave internal surface, to compensate for the greater contraction of the central parts of the metal in cooling than the edges. The ingots weigh about 2 ounces each, and are $\frac{3}{4}$ of an inch broad.

2. *The forging.*—When the ingot is cold, the French gold-beaters hammer it out on a mass of steel 4 inches long and 3 broad. The hammer for this purpose is called the forging hammer. It weighs about 3 pounds, with a head at one end and a wedge at the other, the head presenting a square face of $1\frac{1}{2}$ inches. Its handle is 6 inches long. The workman reduces the ingot to the thickness of $\frac{1}{6}$ of an inch at most; and during this operation he anneals it whenever its substance becomes hard and apt to crack. The English gold-beaters omit this process of hammering.

3. *The lamination.*—The rollers employed for this purpose should be of a most perfectly cylindrical figure, a polished surface, and so powerful as not to bend or yield in the operation. The ultimate excellence of the gold leaf depends very much on the precision with which the riband is extended in the rolling press. The laminating machine represented under the article MINT, is an excellent pattern for this purpose. The gold-beater desires to have a riband of such thinness that a square inch of it will weigh $6\frac{1}{2}$ grains. Frequent annealings are requisite during the lamination.

4. *Beating.*—The riband of gold being thus prepared uniform, the gold-beater cuts it with shears into small squares of an inch each, having previously divided it with compasses, so that the pieces may be of as equal weight as possible. These squares are piled over each other in parcels of 150, with a piece of fine calf-skin vellum interposed between each, and about 20 extra vellums at the top and bottom. These vellum leaves are about 4 inches square, on whose centre lie the gold laminæ of an inch square. This packet is kept together by being thrust into a case of strong parchment open at the ends, so as to form a belt or band, whose open sides are covered in by a second case drawn over the packet at right angles to the first. Thus the packet becomes sufficiently compact to bear beating with a hammer of 15 or 16 pounds weight, having a circular face nearly 4 inches diameter, and somewhat convex, whereby it strikes the centre of the packet most forcibly, and thus squeezes out the plates laterally.

The beating is performed on a very strong bench or stool framed to receive a heavy block of marble, about 9 inches square on the surface, enclosed upon every side by woodwork, except the front where a leather apron is attached, which the workman lays before him to preserve any fragments of gold that may fall out of the packet. The hammer is short-handled, and is managed by the workman with one hand; who strikes fairly on the middle of the packet, frequently turning it over to beat both sides alike; a feat dexterously done in the interval of two strokes, so as not to lose a blow. The packet is occasionally bent or rolled between the hands, to loosen the leaves and secure the ready extension of the gold; or it is taken to pieces to examine the gold, and to shift the central leaves to the outside, and vice versa, that every thing may be equalized. Whenever the gold plates have extended, under this treatment, to nearly the size of the vellum, they are removed from the packet, and cut into four equal squares by a knife. They are thus reduced to nearly the same size as at first, and are again made up into packets and enclosed as before, with this difference, that skins prepared from ox-gut are now interposed between each gold leaf instead of vellum. The second course of beating is performed with a smaller hammer, about 10 pounds in weight, and is continued till the leaves are extended to the size of the skins. During this period the packet must be often folded, to render the gold as loose as possible between the membranes; otherwise the leaves are easily chafed and broken. They are once more spread on a cushion, and subdivided into four square pieces by means of two pieces of cane cut to very sharp edges, and fixed down transversely on a board. This rectangular cross being applied on each leaf, with slight pressure, divides it into four equal portions. These are next made up into a third packet of convenient thickness, and finally hammered out to the area of fine gold leaf, whose average size is from 3 to $3\frac{1}{2}$ inches square. The leaves will now have obtained an area 192 times greater than the plates before the hammering begun. As these were originally an inch square, and 75 of them weighed an ounce ($= 6\frac{1}{2} \times 75 = 487\frac{1}{2}$), the surface of the finished leaves will be $192 \times 75 = 14{,}400$ square inches, or 100 square feet per ounce troy. This is by no means the ultimate degree of attenuation, for an ounce may be hammered so as to cover 160 square feet; but the waste incident in this case, from the number of broken leaves, and the increase and nicety of the labor, make this an unprofitable refinement; while the gilder finds such thin leaves to make less durable and satisfactory work.

The finished leaves of gold are put up in small books made of single leaves of soft paper, rubbed over with red chalk to prevent adhesion between them. Before putting the leaves in these books, however, they are lifted one by one with a delicate pair of pincers out of the finishing packet, and spread out on a leather cushion by blowing them flat down. They are then cut to one size, by a sharp-edge square moulding of cane, glued on a flat board. When this square-framed edge is pressed upon the gold, it cuts it to the desired size and shape. Each book commonly contains 25 gold leaves.

I shall now describe some peculiarities of the French practice of gold beating. The workman cuts the laminated ribands of an inch broad into portions an inch and a half long. These are called *quartiers.* He takes 24 of them, which he places exactly over each other, so as to form a thickness of about an inch, the riband being $\frac{1}{2}$ of a line, or $\frac{1}{24}$ of an inch thick; and he beats them together on the steel slab with the round face (*panne*) of the hammer, so as to stretch them truly out into the square form. He begins by extending the substance towards the edges, thereafter advancing towards the middle; he then does as much on the other side, and finally hammers the centre. By repeating this mode of beating as often as necessary, he reduces at once all the *quartiers* (squares) of the same packet, till none of them is thicker than a leaf of gray paper, and of the size of a square of 2 inches each side.

When the *quartiers* are brought to this state, the workman takes 56 of them, which he piles over each other, and with which he forms the first packet (*caucher*) in the manner already described; only two leaves of vellum are interposed between each gold leaf. The empty leaves of vellum at the top and bottom of the packet are called *emplures.* They are 4 inches square, as well as the parchment pieces.

The packet thus prepared forms a rectangular parallelopiped; it is enclosed in two sheaths, composed each of several leaves of parchment applied to each, and glued at the two sides, forming a bag open at either end.

The block of black marble is a foot square at top, and 18 inches deep, and is framed as above described. The hammer used for beating the first packet is called the flat, or the enlarging hammer; its head is round, about 5 inches in diameter, and very slightly convex. It is 6 inches high, and tapers gradually from its head to the other extremity, which gives it the form of a hexagonal truncated pyramid. It weighs 14 or 15 pounds.

The French gold-beaters employ, besides this hammer, three others of the same form; namely, 1. The *commencing hammer,* which weighs 6 or 7 pounds, has a head 4 inches in diameter, and is more convex than the former. 2. The *spreading hammer* (*marteau à chasser*); its head is two inches diameter, more convex than the last, and weighs only 4 or 5 pounds. 3. The *finishing hammer;* it weighs 12 or 13 pounds, has a head four inches diameter, and is the most convex of all.

The beating processes do not differ essentially from the English described above. The vellum is rubbed over with fine calcined Paris plaster, with a hare's foot. The skin of the gold-beater is a pellicle separated from the outer surface of ox-gut; but before being employed for this purpose, it must undergo two preparations. 1. It is sweated, in order to expel any grease it may contain. With this view, each piece of membrane is placed between two leaves of white paper; several of these pairs are piled over each other, and struck strongly with a hammer, which drives the grease from the gut into the paper.

2. A body is given to the pieces of gut; that is, they are moistened with an infusion

of cinnamon, nutmeg, and other warm and aromatic ingredients, in order to preserve them; an operation repeated after they have been dried in the air. When the leaves of skin are dry, they are put in a press, and are now ready for use. After the parchment, vellum, and gut membrane have been a good deal hammered, they become unfit for work, till they are restored to proper flexibility, by being placed leaf by leaf between leaves of white paper, moistened sometimes with vinegar, at others with white wine. They are left in this predicament for 3 or 4 hours, under compression of a plank loaded with weights. When they have imbibed the proper humidity, they are put between leaves of parchment 12 inches square, and beat in that situation for a whole day. They are then rubbed over with fine calcined gypsum, as the vellum was originally. The gut-skin is apt to contract damp in standing, and is therefore dried before being used.

The average thickness of common gold leaf is $\frac{1}{282000}$ of an inch.

The art of Gilding.—This art consists in covering bodies with a thin coat of gold; which may be done either by mechanical or chemical means. The mechanical mode is the application of gold leaf or gold powder to various surfaces, and their fixation by various means. Thus gold may be applied to wood, plaster, pasteboard, leather; and to metals, such as silver, copper, iron, tin, and bronze; so that gilding, generally speaking, includes several arts, exercised by very different classes of tradesmen.

I. *Mechanical Gilding.*—Oil gilding is the first method under this head, as oil is the fluid most generally used in the operation of this mechanical art. The following process has been much extolled at Paris.

1. A coat of *impression* is to be given first of all, namely, a coat of white lead paint, made with drying linseed oil, containing very little oil of turpentine.

2. Calcined ceruse is to be ground very well with unboiled linseed oil, and tempered with essence of turpentine, in proportion as it is laid on. Three or four coats of this *hard tint* are to be applied evenly and dryly on the ornaments and the parts which are to be most carefully gilded.

3. The *Gold color* is then to be smoothly applied. This is merely the dregs of the colors, ground and tempered with oil, which remain in the little dish in which painters clean their brushes. This substance is extremely rich and gluey; after being ground up, and passed through fine linen cloth, it forms the ground for gold leaf.

4. When the gold color is dry enough to catch hold of the leaf gold, this is spread on the cushion, cut into pieces, and carefully applied with the palette knife, pressed down with cotton, and in the small ornaments with a fine brush.

5. If the gildings be for outside exposure, as balconies, gratings, statues, &c., they must not be varnished, as simple oil gilding stands better; for when it is varnished, a bright sun-beam, acting after heavy rain, gives the gilding a jagged appearance. When the objects are inside ones, a coat of spirit varnish may be passed over the gold leaf, then a glow from the gilder's chafing dish may be given, and finally a coat of oil varnish. The workman who causes the chafing dish to glide in front of the varnished surface, must avoid stopping for an instant opposite any point, otherwise he would cause the varnish to boil and blister. This heat brings out the whole transparency of the varnish and lustre of the gold.

Oil Gilding is employed, with varnish polish, upon equipages, mirror-frames, and other furniture. The following method is employed by eminent gilders at Paris.

1. White lead, with half its weight of yellow ochre, and a little litharge, are separately ground very fine; and the whole is then tempered with linseed oil, thinned with essence of turpentine, and applied in an evenly coat, called *impression.*

2. When this coat is quite dry, several coats of the hard tint are given, even so many as 10 or 12, should the surface require it, for smoothing and filling up the pores. These coats are given daily, leaving them to dry in the interval in a warm sunny exposure.

3. When the work is perfectly dry, it is first softened down with pumice stone and water, afterwards with worsted cloth and very finely powdered pumice, till the *hard tint* give no reflection, and be smooth as glass.

4. With a camel's hair brush, there must be given lightly and with a gentle heat, from 4 to 5 coats at least, and even sometimes double that number, of fine lac varnish.

5. When these are dry, the grounds of the panels and the sculptures must be first polished with shave-grass (*de la prèle*); and next with putty of tin and tripoli, tempered with water, applied with woollen cloth; by which the varnish is polished till it shines like a mirror.

6. The work thus polished is carried into a hot place, free from dust, where it receives very lightly and smoothly a thin coat of *gold color,* much softened down. This coat is passed over it with a clean soft brush, and the thinner it is the better.

7. Whenever the gold color is dry enough to take the gold, which is known by laying the back of the hand on a corner of the frame work, the gilding is begun and finished as usual.

8. The gold is smoothed off with a very soft brush, one of camel's hair, for example of three fingers' breadth; after which it is left to dry for several days.

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9. It is then varnished with a spirit of wine varnish; which is treated with the chafing dish as above described.

10. When this varnish is dry, two or three coats of copal or oil varnish are applied, at intervals of two days.

11. Finally, the panels are polished with a worsted cloth, imbued with tripoli and water, and lustre is given by friction with the palm of the hand, previously softened with a little olive oil, taking care not to rub off the gold.

In this country, *burnished gilding* is practised by first giving a ground of size whiting, in several successive coats; next applying gilding size; and then the gold leaf, which is burnished down with agate, or a dog's tooth.

Gilding in distemper of the French, is the same as our burnished gilding. Their process seems to be very elaborate, and the best consists of 17 operations; each of them said to be essential.

1. *Encollage*, or the *glue coat*. To a decoction of wormwood and garlic in water, strained through a cloth, a little common salt and some vinegar are added. This composition, as being destructive of worms in wood, is mixed with as much good glue; and the mixture is spread in a hot state, with a brush of boar's hair. When plaster or marble is to be gilded, the salt must be left out of the above composition, as it is apt to attract humidity in damp places, and to come out as a white powder on the gilding. But the salt is indispensable for wood. The first glue coating is made thinner than the second.

2. *White preparation*. This consists in covering the above surface with 8, 10, or 12 coats of Spanish white, mixed up with strong size, each well worked on with the brush, and in some measure incorporated with the preceding coat, to prevent their peeling off in scales.

3. *Stopping up* the pores, with thick whiting and glue, and smoothing the surface with dog-skin.

4. Polishing the surface with pumice-stone and very cold water.

5. *Reparation;* in which a skilful artist retouches the whole.

6. *Cleansing;* with a damp linen rag, and then a soft sponge.

7. *Prêler*. This is rubbing with horse's tail (*shave-grass*) the parts to be yellowed, in order to make them softer.

8. *Yellowing*. With this view *yellow ochre* is carefully ground in water, and mixed with transparent colorless size. The thinner part of this mixture is applied hot over the white surface with a fine brush, which gives it a fine yellow hue.

9. *Ungraining* consists in rubbing the whole work with shave-grass, to remove any granular appearance.

10. *Coat of assiette; trencher coat*. This is the composition on which the gold is to be laid. It is composed of Armenian bole, 1 pound; bloodstone (hematite), 2 ounces; and as much galena; each separately ground in water. The whole are then mixed together, and ground up with about a spoonful of olive oil. The *assiette* well made and applied gives beauty to the gilding. The *assiette* is tempered with a white sheep-skin glue, very clear and well strained. This mixture is heated and applied in three successive coats, with a very fine long-haired brush.

11. *Rubbing*, with a piece of dry, clean linen cloth; except the parts to be burnished, which are to receive other two coats of *assiette* tempered with glue.

12. *Gilding*. The surface, being damped with cold water (iced in summer), has then the gold leaf applied to it. The hollow grounds must always be gilded before the prominent parts. Water is dexterously applied by a soft brush, immediately behind the gold leaf, before laying it down, which makes it lie smoother. Any excess of water is then removed with a dry brush.

13. *Burnishing* with bloodstone.

14. *Deadening*. This consists in passing a thin coat of glue, slightly warmed, over the parts that are not to be burnished.

15. *Mending;* that is, moistening any broken points with a brush, and applying bits of gold leaf to them.

16. The *vermeil* coat. Vermeil is a liquid which gives lustre and fire to the gold; and makes it resemble *or moulu*. It is composed as follows: 2 ounces of annotto, 1 ounce of gamboge, 1 ounce of vermilion, half an ounce of dragon's blood, 2 ounces of salt of tartar, and 18 grains of saffron, are boiled in a litre (2 pints English) of water, over a slow fire, till the liquid be reduced to a fourth. The whole is then passed through a silk or muslin sieve. A little of this is made to glide lightly over the gold, with a very soft brush.

17. *Repassage* is passing over the dead surfaces a second coat of deadening glue, which must be hotter than the first. This finishes the work, and gives it strength.

Leaf gilding, on paper or vellum, is done by giving them a coat of gum water or fine size, applying the gold leaf ere the surfaces be hard dry, and burnishing with agate.

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Gold lettering, on bound books, is given without size, by laying the gold leaf on the leather, and imprinting it with hot brass types.

The *edges of the leaves of books are gilded* while they are in the press, where they have been cut smooth, by applying a solution of isinglass in spirits, and laying on the gold when the edges are in a proper state of dryness. The French workmen employ a ground of Armenian bole, mixed with powdered sugar-candy, by means of white of egg. This ground is laid very thin upon the edges, after fine size or gum water has been applied; and when the ground is dry it is rubbed smooth with a wet rag, which moistens it sufficiently to take the gold.

Japanner's gilding is done by sprinkling or daubing with wash leather, some gold powder, over an oil sized surface, mixed with oil of turpentine. This gives the appearance of frosted gold. The gold powder may be obtained, either by precipitating gold from its solution in *aqua regia* by a solution of pure sulphate of iron, or by evaporating away the mercury from some gold amalgam.

II. *Chemical gilding*, or the application of gold by chemical affinity to metallic surfaces.

A compound of copper with one seventh of brass is the best metal for gilding on; copper by itself being too soft and dark colored. Ordinary brass, however, answers very well. We shall describe the process of wash gilding, with M. D'Arcet's late improvements, now generally adopted in Paris.

Wash gilding consists in applying evenly an amalgam of gold to the surface of a copper alloy, and dissipating the mercury with heat, so as to leave the gold film fixed. The surface is afterwards burnished or deadened at pleasure. The gold ought to be quite pure, and laminated to facilitate its combination with the mercury; which should also be pure.

Preparation of the amalgam. After weighing the fine gold, the workman puts it in a crucible, and as soon as this becomes faintly red, he pours in the requisite quantity of mercury; which is about 8 to 1 of gold. He stirs up the mixture with an iron rod, bent hookwise at the end, leaving the crucible on the fire till he perceives that all the gold is dissolved. He then pours the amalgam into a small earthen dish containing water, washes it with care, and squeezes out of it with his fingers all the running mercury that he can. The amalgam that now remains on the sloping sides of the vessel is so pasty as to preserve the impression of the fingers. When this is squeezed in a shamoy leather bag, it gives up much mercury; and remains an amalgam, consisting of about 33 of mercury, and 57 of gold, in 100 parts. The mercury which passes through the bag, under the pressure of the fingers, holds a good deal of gold in solution; and is employed in making fresh amalgam.

Preparation of the mercurial solution. The amalgam of gold is applied to brass, through the intervention of pure nitric acid, holding in solution a little mercury.

100 parts of mercury, and 110 parts by weight of pure nitric acid, specific gravity 1·33, are to be put into a glass matrass. On the application of a gentle heat the mercury dissolves with the disengagement of fumes of nitrous gas, which must be allowed to escape into the chimney. This solution is to be diluted with about 25 times its weight of pure water, and bottled up for use.

1. *Annealing.*—The workman anneals the piece of bronze after it has come out of the hands of the turner and engraver. He sets it among burning charcoal, or rather peats, which have a more equal and lively flame; covering it quite up, so that it may be oxydized as little as possible, and taking care that the thin parts of the piece do not become hotter than the thicker. This operation is done in a dark room, and when he sees the piece of a cherry red color, he removes the fuel from about it, lifts it out with long tongs, and sets it to cool slowly in the air.

2. The *decapage.*—The object of this process is to clear the surface from the coat of oxyde which may have formed upon it. The piece is plunged into a bucket filled with extremely dilute sulphuric acid; it is left there long enough to allow the coat of oxyde to be dissolved, or at least loosened; and it is then rubbed with a hard brush. When the piece becomes perfectly bright, it is washed and dried. Its surface may however be still a little variegated; and the piece is therefore dipped in nitric acid, specific gravity 1·33, and afterwards rubbed with a long-haired brush. The addition of a little common salt to the dilute sulphuric acid would probably save the use of nitric acid, which is so apt to produce a new coat of oxyde. It is finally made quite dry (after washing in pure water), by being rubbed well with tanners' dry bark, saw-dust, or bran. The surface should now appear somewhat de-polished; for when it is very smooth, the gold does not adhere so well.

Application of the amalgam.—The gilder's *scratch-brush* or pencil, made with fine brass wire, is to be dipped into the solution of nitrate of mercury, and is then to be drawn over a lump of gold amalgam, laid on the sloping side of an earthen vessel, after which it is to be applied to the surface of the brass. This process is to be repeated, dipping the brush into the solution, and drawing it over the amalgam, till the whole surface to be gilded is coated with its just proportion of gold. The piece is then washed in a body of water, dried, and put to the fire to volatilize the mercury. If one coat of gilding be insufficient, the piece is washed over anew with amalgam, and the operation recommenced till the work prove satisfactory.

4. *Volatilization of the mercury.*—Whenever the piece is well coated with amalgam, the gilder exposes it to glowing charcoal, turning it about, and heating it by degrees to the proper point; he then withdraws it from the fire, lifts it with long pincers, and, seizing it in his left hand, protected by a stuffed glove, he turns it over in every direction, rubbing and striking it all the while with a long-haired brush, in order to equalize the amalgam. He now restores the piece to the fire, and treats it in the same way till the mercury be entirely volatilized, which he recognises by the hissing sound of a drop of water let fall on it. During this time he repairs the defective spots, taking care to volatilize the mercury very slowly. The piece, when thoroughly coated with gold, is washed, and scrubbed well with a brush in water acidulated with vinegar.

If the piece is to have some parts burnished, and others dead, the parts to be burnished are covered with a mixture of Spanish white, bruised sugar-candy, and gum dissolved in water. This operation is called in French *epargner* (*protecting*). When the gilder has *protected* the burnished points, he dries the piece, and carries the heat high enough to expel the little mercury which might still remain on it. He then plunges it, while still a little hot, in water acidulated with sulphuric acid, washes it, dries it, and gives it the burnish.

5. The *burnish* is given by rubbing the piece with burnishers of hematite (bloodstone). The workman dips his burnisher in water sharpened with vinegar, and rubs the piece always in the same direction backwards and forwards, till it exhibits a fine polish, and a complete metallic lustre. He then washes it in cold water, dries it with fine linen cloth, and concludes the operation by drying it slowly on a grating placed above a chafing dish of burning charcoal.

6. The *deadening* is given as follows. The piece, covered with the *protection* on those parts that are to be burnished, is attached with an iron wire to the end of an iron rod, and is heated strongly so as to give a brown hue to the *epargne* by its partial carbonization. The gilded piece assumes thus a fine tint of gold; and is next coated over with a mixture of sea salt, nitre, and alum, fused in the water of crystallization of the latter salt. The piece is now restored to the fire, and heated till the saline crust which covers it becomes homogeneous, nearly transparent, and enters into true fusion. It is then taken from the fire and suddenly plunged into cold water, which separates the saline crust, carrying away even the coat of *epargne*. The piece is lastly passed through very weak nitric acid, washed in a great body of water, and dried by exposure either to the air, over a drying stove, or with clean linen cloths.

7. *Of or-moulu color.*—When it is desired to put a piece of gilded bronze into *or-moulu* color, it must be less scrubbed with the scratch-brush than usual, and made to *come back again* by heating it more strongly than if it were to be deadened, and allowing it then to cool a little. The *or-moulu* coloring is a mixture of hematite, alum, and sea salt. This mixture is to be thinned with vinegar, and applied with a brush so as to cover the gilded brass, with reserve of the burnished parts. The piece is then put on glowing coals, urged a little by the bellows, and allowed to heat till the color begins to blacken. The piece ought to be so hot that water sprinkled on it may cause a hissing noise. It is then taken from the fire, plunged into cold water, washed, and next rubbed with a brush dipped in vinegar, if the piece be smooth, but if it be chased, weak nitric acid must be used. In either case, it must be finally washed in a body of pure water, and dried over a gentle fire.

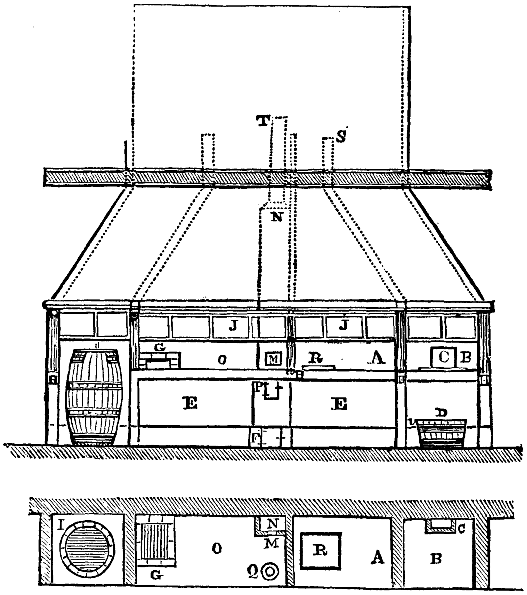
8. *Of red gold color.*—To give this hue, the piece, after being coated with amalgam and heated, is in this hot state to be suspended by an iron wire, and tempered with the composition known under the name of gilder's wax; made with yellow wax, red ochre, verdigris, and alum. In this state it is presented to the flame of a wood fire, is heated strongly, and the combustion of its coating is favored by throwing some drops of the wax mixture into the burning fuel. It is now turned round and round over the fire, so that the flame may act equally. When all the wax of the coloring is burned away, and when the flame is extinguished, the piece is to be plunged in water, washed, and scrubbed with the scratch-brush and pure vinegar. If the color is not beautiful, and quite equal in shade, the piece is coated with verdigris dissolved in vinegar, dried over a gentle fire, plunged in water, and scrubbed with pure vinegar, or even with a little weak nitric acid if the piece exhibit too dark a hue. It is now washed, burnished, washed anew, wiped with linen cloth, and finally dried over a gentle fire.

The following is the outline of a complete gilding factory, as now fitted up at Paris.

Fig. 738. Front elevation and plan of a complete gilding workshop.

P Furnace of *appel*, or draught, serving at the same time to heat the deadening **pan** *(poêlon au mat)*

738



F. Ashpit of this furnace.

N. Chimney of this furnace constructed of bricks, as far as the contraction of the great chimney s of the forge, and which is terminated by a summit pipe rising 2 or 3 yards above this contraction.

B. Forge for annealing the pieces of bronze; for drying the gilded pieces, &c.

C. Chimney of communication between the annealing forge B, and the space D below the forge. This chimney serves to carry the noxious fumes into the great vent of the factory.

U. Bucket for the brightening operation.

A. Forge for passing the amalgam over the piece.

R. Shelf for the brushing operations

E E. Coal cellarets.

O. Forge for the deadening process.

G. Furnace for the same.

M. An opening into the furnace of *appel*, by which vapors may be let off from any operation by taking out the plug at M.

I. Cask in which the pieces of gilded brass are plunged for the deadening process. The vapors rising thence are carried up the general chimney.

J J. Casement with glass panes, which serves to contract the opening of the hearths, without obstructing the view. The casement may be rendered moveable to admit larger objects.

H H. Curtains of coarse cotton cloth, for closing at pleasure, in whole or part, one or several of the forges or hearths, and for quickening the current of air in the places where the curtains are not drawn.

Q. Opening above the draught furnace, which serves for the heating of the *poêlon au mat* (deadening pan).

Gilding on polished iron and steel.—If a nearly neutral solution of gold in muriatic acid be mixed with sulphuric ether, and agitated, the ether will take up the gold, and float above the denser acid. When this auriferous ether is applied by a hair pencil to brightly polished iron or steel, the ether flies off, and the gold adheres. It must be fixed by polishing with the burnisher. This gilding is not very rich or durable. In fact, the affinity between gold and iron is feeble, compared to that between gold and copper or silver. But polished iron, steel, and copper, may be gilded with heat, by gold leaf. They are first heated till the iron takes a bluish tint, and till the copper has attained tc like temperature; a first coat of gold leaf is now applied, which is pressed gently down with a burnisher, and then exposed to a gentle heat. Several leaves either single or double are thus applied in succession, and the last is burnished down cold.

Cold gilding.—Sixty grains of fine gold and 12 of rose copper are to be dissolved in two ounces of aqua regia. When the solution is completed, it is to be dropped on clean linen rags, of such bulk as to absorb all the liquid. They are then dried, and burned into ashes. These ashes contain the gold in powder.

When a piece is to be gilded, after subjecting it to the preliminary operations of softening or annealing and brightening, it is rubbed with a moistened cork, dipped in the above powder, till the surface seems to be sufficiently gilded. Large works are thereafter burnished with pieces of hematite, and small ones with steel burnishers, along with soap water.

In gilding small articles, as buttons, with amalgam, a portion of this is taken equivalent to the work to be done, and some nitrate of mercury solution is added to it in a wooden trough; the whole articles are now put in, and well worked about with a hard brush, till their surfaces are equably coated. They are then washed, dried, and put altogether into an iron frying-pan, and heated till the mercury begins to fly off, when they are turned out into a cap, in which they are tossed and well stirred about with a painter's brush. The operation must be repeated several times for a strong gilding. The surfaces are finally brightened by brushing them along with small beer or ale grounds.

Gold wire is formed by drawing a cylindrical rod of the metal, as pure as may be, through a series of holes punched in an iron plate, diminishing progressively in size. The gold, as it is drawn through, becomes hardened by the operation, and requires frequent annealing.

Gold thread, or *spun gold,* is a flatted silver-gilt wire, wrapped or laid over a thread of yellow silk, by twisting with a wheel and iron bobbins. By the aid of a mechanism like the Braiding Machine, a number of threads may thus be twisted at once by one master wheel. The principal nicety consists in so regulating the movements that the successive volutions of the flatted wire on each thread may just touch one another, and form a continuous covering. The French silver for gilding is said to be alloyed with 5 or 6 pennyweights, and ours with 12 pennyweights of copper in the pound troy. The gold is applied in leaves of greater or less thickness, according to the quality of the gilt wire. The smallest proportion formerly allowed in this country by act of parliament, was 100 grains of gold to one pound, or 5760 grains of silver; but more or less may now be used. The silver rod is encased in the gold leaf, and the compound cylinder is then drawn into round wire down to a certain size, which is afterwards flatted in a rolling mill such as is described under MINT.

The liquor employed by goldsmiths to bring out a rich color upon the surface of their trinkets, is made by dissolving 1 part of sea salt, 1 part of alum, 2 parts of nitre, in 3 or 4 of water. This pickle or sauce, as it is called, takes up not only the copper alloy, but a notable quantity of gold; the total amount of which in the Austrian empire, has been estimated annually at 47,000 francs. To recover this gold, the liquor is diluted with at least twice its bulk of boiling water; and a solution of very pure green sulphate of iron is poured into it. The precipitate of gold is washed upon a filter, dried, and purified by melting in a crucible along with a mixture of equal parts of nitre and borax.

Gold refining.—The following process has been patented as a foreign invention by Mr. W. E. Newton in January, 1851.

It consists, 1., in reducing argentiferous or any other gold bullion to a granulated, or spongy, or disintegrated molecular condition by fusion therewith of zinc, or some other metal baser than silver, and the subsequent removal of the zinc by dilute sulphuric or other acid; that is, the reducing of the gold bullion to a state to allow of the removal by acids of the silver and other impurities contained therein, so as to fit it for coinage and other purposes without quartation with silver or any other intermediate process. And

2., in pulverizing by grinding or concussion gold bullion, rendered brittle by union with lead, solder, or other suitable metal, the silver and other impurities being removed by acids in this as in the preceding case, and recovered from the acid solution by any of the known chemical means.

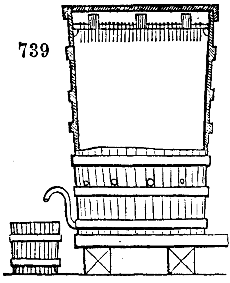
This operation, if properly conducted, will produce fine ductile gold in a state of great purity; that is, containing from 98·5 to 99·5 per cent. of pure gold.

GONG-GONG; or *tam-tam* of the Chinese; a kind of cymbal made of a copper alloy, described towards the end of the article COPPER.

GONIOMETER, is the name of a little instrument made either on mechanical or optical principles, for measuring the angles of crystals. It is indispensable to the mineralogist.

GRADUATOR, called by its contriver M. Wagenmann, *Essigbilder*, which means, in German, vinegar-maker, is represented in *fig.* 739. It is an oaken tub, 5½ feet high, 3½ feet wide at top, and 3 at bottom, set upon wooden beams, which raise its bottom

739



about 14 inches from the floor. At a distance of 15 inches above the bottom, the tub is pierced with a horizontal row of 8 equidistant round holes, of an inch in diameter. At 5 inches beneath the mouth of the tub, a thick beech wood hoop is made fast to the inner surface, which supports a circular oaken shelf, leaving a space round its edge of 1¼ inches, which is stuffed water-tight with hemp or tow. In this shelf, 400 holes at least must be bored, about ⅛ of an inch in diameter, and 1½ inches apart; and each of these must be loosely filled with a piece of packthread, or cotton wick, which serves to filter the liquid slowly downwards. In the same shelf there are likewise four larger holes of 1½ inches diameter, and 18 inches apart, each of which receives air-tight a glass tube 3 or 4 inches long, having its ends projecting above and below the shelf. These tubes serve to allow the air that enters by the 8 circumferential holes, to circulate freely through the graduator. The mouth of the tube is covered with a wooden lid, in whose middle is a hole for the insertion of a funnel, when the liquor of acetification requires to be introduced. One inch above the bottom, a hole is bored for receiving a syphon-formed discharge pipe, whose upper curvature stands one inch below the level of the holes in the side of the tub, to prevent the liquor from rising so high as to overflow through them. The syphon is so bent as to retain a body of liquor 12 inches deep above the bottom of the tub, and to allow the excess only to escape into the subjacent receiver. In the upper part of the graduator, but under the shelf, the bulb of a thermometer is inserted through the side, some way into the interior, having a scale exteriorly. The whole capacity of the cask from the bottom up to within one inch of the perforated shelf, is to be filled with thin shavings of beech wood, grape stalks, or birch twigs, previously imbued with vinegar. The manner of using this simple apparatus is described under Acetic Acid.

GRANITE is a compound rock, essentially composed of quartz, feldspar, and mica, each in granular crystals. It constitutes the lowest of the geological formations, and therefore has been supposed to serve as a base to all the rest. It is the most durable material for building, as many of the ancient Egyptian monuments testify.

The obelisk in the place of Saint Jean de Lateran at Rome, which was quarried at Syene, under the reign of Zetus, king of Thebes, 1300 years before the Christian era; and the one in the place of Saint Pierre, also at Rome, consecrated to the Sun by a son of Sesostris, have resisted the weather for fully 3000 years. On the other hand there are many granites, especially those in which feldspar predominates, which crack and crumble down in the course of a few years. In the same mountain, or even in the same quarry, granites of very different qualities as to soundness and durability occur. Some of the granites of Cornwall and Limousin readily resolve themselves into a white kaolin or argillaceous matter, from which pottery and porcelain are made.

Granite, when some time dug out of the quarry, becomes refractory, and difficult to cut. When this rock is intended to be worked it should be kept under water; and that variety ought to be selected which contains least feldspar, and in which the quartz or gray crystals predominate.

GRANULATION is the process by which metals are reduced to minute grains. It is effected by pouring them, in a melted state, through an iron cullender pierced with small holes, into a body of water; or directly upon a bundle of twigs immersed in water. In this way copper is granulated into bean shot, and silver alloys are granulated preparatory to Parting; which see.

GRAPHITE (*Plombagine*, Fr.; *Reissblei*, Germ.) is a mineral substance of a lead or iron gray color, a metallic lustre, soft to the touch, and staining the fingers with a lead gray hue. Spec. grav. 2·08 to 2·45. It is easily scratched, or cut with a steel edge, and displays the metallic lustre in its interior. Burns with great difficulty in the outward flame of the blow-pipe. It consists of carbon in a peculiar state of aggregation, with an extremely minute and apparently accidental impregnation of iron. Graphite, called also plumbago and black lead, occurs in gneiss, mica slate, and their subordinate clay slates and lime stones; in the form of masses, veins, and kidney-shaped disseminated pieces; as also in the transition slate, as at Borrodale in Cumberland, where the most precious deposite exists, both in reference to extent and quality, for making pencils. It has been found also among the coal strata, as near Cumnock in Ayrshire. This substance is employed for counteracting friction between rubbing surfaces of wood or metal, for making crucibles and portable furnaces, for giving a gloss to the surface of cast iron, &c. See Plumbago, for some remarks concerning the Cumberland mine.

GRAUWACKE, or GREYWACKE, is a rock formation, composed of pieces of quartz, flinty slate, feldspar, and clay slate, cemented by a clay-slate basis; the pieces varying in size from small grains to a hen's egg.

GRAY DYE. (*Teinture grise*, Fr.; *Graufärbe*, Germ.) The gray dyes, in their numerous shades, are merely various tints of black, in a more or less diluted state, from the deepest to the lightest hue.

The dyeing materials are essentially the tannic and gallic acid of galls or other astringents, along with the sulphate or acetate of iron, and occasionally wine stone. Ash gray is given for 30 pounds of woollen stuff, by one pound of gall-nuts, ½ lb. of wine stone (crude tartar), and 2½ lbs. of sulphate of iron. The galls and the wine stone being boiled with from 70 to 80 pounds of water, the stuff is to be turned through the decoction at a boiling heat for half an hour, then taken out, when the bath being refreshed with cold water, the copperas is to be added, and, as soon as it is dissolved, the stuff is to be put in and fully dyed. Or, for 36 pounds of wool; 2 pounds of tartar, ½ pound of galls, 3 pounds of sumach, and 2 pounds of sulphate of iron are to be taken. The tartar being dissolved in 80 pounds of boiling water, the wool is to be turned through the solution for half an hour, and then taken out. The copper being filled up to its former level with fresh water, the decoction of the galls and sumach is to be poured in, and the wool boiled for half an hour in the bath. The wool is then taken out, while the copperas is being added and dissolved; after which it is replaced in the bath, and dyed gray with a gentle heat.

If the gray is to have a yellow cast, instead of the tartar, its own weight of alum is to be taken; instead of the galls, one pound of old fustic; instead of the copperas, ¾ of a pound of Saltzburg vitriol, which consists, in 22⅝ parts, of 17 of sulphate of iron, and 5⅝ of sulphate of copper; then proceed as above directed. Or the stuff may be first stained in a bath of fustic, next in a weak bath of galls with a little alum; then the wool being taken out, a little vitriol (common or Saltzburg) is to be put in, previously dissolved in a decoction of logwood; and in this bath the dye is completed.

Pearl gray is produced by passing the stuff first through a decoction of sumach and logwood (2 lbs. of the former to one of the latter), afterwards through a dilute solution of sulphate or acetate of iron; and finishing it in a weak bath of weld containing a little alum. *Mouse-gray* is obtained, when with the same proportions as for ash-gray, a small quantity of alum is introduced.

For several other shades, as tawny-gray, iron-gray, and slate-gray, the stuff must receive a previous blue ground by dipping it in the indigo vat; then it is passed first through a boiling bath of sumach with galls, and lastly through the same bath at a lower temperature after it has received the proper quantity of solution of iron.

For dyeing silk gray, fustet, logwood, sumach, and elder-tree bark, are employed instead of galls. Archil and annotto are frequently used to soften and beautify the tint.

The mode of producing gray dyes upon cotton has been sufficiently explained in the articles CALICO PRINTING and DYEING.

GREEN DYE is produced by the mixture of a blue and yellow dye, the blue being first applied. See DYEING; as also BLUE and YELLOW DYES, and CALICO PRINTING.

GREEN PAINTS. (*Couleurs vertes*, Fr.; *Grüne pigmente*, Germ.) Green, which is so common a color in the vegetable kingdom, is very rare in the mineral. There is only one metal, copper, which affords in its combinations the various shades of green in general use. The other metals capable of producing this color are, chromium in its protoxyde, nickel in its hydrated oxyde, as well as its salts, the seleniate, arseniate, and sulphate; and titanium in its prussiate.

Green pigments are prepared also by the mixture of yellows and blues; as, for example, the green of Rinman and of Gellert, obtained by the mixture of cobalt blue, and flowers of zinc; that of Barth, made with yellow lake, Prussian blue, and clay; but these paints seldom appear in the market, because the greens are generally extemporaneous preparations of the artists.

Mountain green consists of the hydrate, oxyde, or carbonate of copper, either factitious, or as found in nature.

Bremen or Brunswick green is a mixture of carbonate of copper with chalk or lime, and sometimes a little magnesia or ammonia. It is improved by an admixture of white lead. It may be prepared by adding ammonia to a mixed solution of sulphate of copper and alum.

Frise green is prepared with sulphate of copper and sal ammoniac.

Miltis green is an arseniate of copper; made by mixing a solution of acetate or sulphate of copper with arsenite of potash. It is in fact Scheele's green.

Sap green is the inspissated juice of buckthorn berries. These are allowed to ferment for 8 days in a tub, then put in a press, adding a little alum to the juice, and concentrated by gentle evaporation. It is lastly put up in pigs' bladders, where it becomes dry and hard

Schweinfurt green; see SCHWEINFURT.

Verona green is merely a variety of the mineral called green earth.

GREEN VITRIOL is sulphate of iron in green crystals.

GROWAN. The name given by the Cornish miners to *granite*, and to rocks of like structure.

GUAIAC, (*Gaiac*, Fr.; *Guajaharz*, Germ.) is a resin which exudes from the trunk of the *Guaiacum officinale*, a tree which grows in the West India islands. It comes to us in large greenish-brown, semi-transparent lumps, having a conchoidal or splintery fracture, brittle and easy to pulverize. It has an aromatic smell, a bitterish, acrid taste, melts with heat, and has a spec. grav. of from 1·20 to 1·22. It consists of 67·88 carbon; 7·05 hydrogen; and 25·07 oxygen; and contains two different resins, the one of which is soluble in all proportions in ammonia, and the other forms, with water of ammonia, a tarry consistenced mixture. It is soluble in alkaline lyes, in alcohol, incompletely in ether, still less so in oil of turpentine, and not at all in fat oils. Its chief use is in medicine.

GUANO. This extraordinary excrementitious deposite of certain sea-fowls, which occurs in immense quantities upon some parts of the coasts of Peru, Bolivia, and Africa, has lately become an object of great commercial enterprise, and of intense interest to our agricultural world. Four or five years ago it was exhibited and talked of merely as a natural curiosity. No one could then have imagined that in a short period it would be imported from the coasts of the Pacific in such abundance, and at such a moderate price, as to cheer by its fertilizing powers the languid and depressed spirits of the farmers throughout the United Kingdom. Such, however, is now the result, as attested by the concurring reports of almost all the agricultural societies of Great Britain and Ireland. No less than 28,500 tons of guano have been already imported from Peru and Bolivia, 1,500 from Chili, and 8,000 from Africa, altogether 38,000 tons, while more is on the way. The store of it, laid up from time immemorial in the above localities, seems to be quite inexhaustible; especially since it is receiving constant accessions from myriads of cormorants, cranes, &c.

Having been much occupied with the chemical analyses of guano during the last two years for Messrs. Gibbs, of London, and Messrs. Myers, of Liverpool, who are the co-agents of the Peruvian and Bolivian governments, I have enjoyed favorable opportunities of examining samples of every description, and hope to show that many of the analyses of guano hitherto published have been made upon specimens not in their normal or sound state, like the best imported by the above houses from Chincha and Bolivia, but in a certain state of *eremacausis* and decay.

Huano, in the language of Peru, signifies dung; a word spelt by the Spaniards guano. The natives have employed it as a manure from the remotest ages, and have by its means given fertility to the otherwise unproductive sandy soils along their coasts. While Peru was governed by its native incas, the birds were protected from violence by severe laws. The punishment of death was decreed to persons who dared to land on the guaniferous islands during the breeding period of the birds, and to all persons who destroyed them at any time. Overseers were appointed by the government to take care of the guano districts, and to assign to each claimant his due share of the precious dung. The celebrated Baron Von Humboldt first brought specimens to Europe in 1804, which he sent for examination to Foureroy, Vauquelin, and Klaproth, the best analytical chemists of the day; and he spoke of it in the following terms: "The guano is deposited in layers of 50 or 60 feet thick upon the granite of many of the South sea islands off the coast of Peru. During 300 years the coast birds have deposited guano only a few lines in thickness. This shows how great must have been the number of birds, and how many centuries must have passed over in order to form the present guano-beds." The strata have undergone many changes, according to the length of time they have been deposited. Here and there they are covered with silicious sand, and have thus been protected from the influence of the weather; but in other places, they have lain open to the action of light, air, and water, which have produced important changes upon them. Fresh guano is of a whitish or very pale drab color, but it becomes progressively browner and browner by the joint influence of the above three atmospherical agents. Only one guano examined by Fourcroy and Vauquelin was found to contain a fourth of its weight of uric acid combined with ammonia, whence that appears to have been well selected by Baron Von Humboldt. They also found phosphates of ammonia, of lime, with urate and oxalate of ammonia, and some other constituents of little value in agriculture. Klaproth's analysis reported 16 per cent. of urate of ammonia, no less than 12·75 of oxalate of lime, 10 of phosphate of lime, 32 of clay and sand, with 28·75 of water and indeterminate organic matter. From the great proportion of clay and sand, Klaproth's sample of guano was obviously not genuine. I have met with no specimen of Peruvian guano that contained any appreciable quantity of clay, and none that contained above 4 or 5 per cent. of silicious sand.

To Mr. Bland, of the firm of Messrs. Myers and Co., I am indebted for the following valuable information:—

The Chincha islands, which afford the best Peruvian guano, are three in number, and lie in one line from north to south, about half a mile apart. Each island is from five to six miles in circumference, and consists of granite covered with guano in some places to a height of 200 feet, in successive horizontal strata, each stratum being from 3 to 10 inches thick, and varying in color from light to dark brown. No earthy matter whatever is mixed with this vast mass of excrement. At Mr. Bland's visit to these islands in 1842, he observed a perpendicular surface of upward of 100 feet of perfectly uniform aspect from top to bottom. In some parts of these islands, however, the deposite does not exceed 3 or 4 feet in thickness. In several places, where the surface of the guano is 100 feet or more above the level of the sea, it is strewed here and there with masses of granite, like those from the Alpine mountains, which are met with on the slopes of the Jura chain. These seem to indicate an ancient formation for the guano, and terraqueous convulsions since that period. No such granite masses are found imbedded within the guano, but only skeletons of birds.

The good preservation of the Chincha guano is to be ascribed to the absence of rain; which rarely, if ever, falls between the latitude of 14° south, where these islands lie, about 10 miles from the main land, and the latitude of Paquica, on the island of Bolivia, in 21° S. L. By far the soundest cargoes of guano which I have analysed have come from Chincha and Bolivia. Beyond these limits of latitude where rain falls in greater or less abundance, the guano is of less value—and what has been imported from Chili has been found by me far advanced in decay—most of the ammonia and azotised animal substances having been decomposed by moisture, and dissipated in the air (by the *eremacausis* of Liebig), leaving phosphate of lime largely to predominate along with effete organic matter. The range of the American coast from which the guano is taken must therefore be well considered; and should not extend much beyond the Chincha islands as the northern limit, and Paquica, in Bolivia, as the southern.

The relative estimation of guano and nitrate of soda among the Peruvians is well shown by the following fact communicated to me by Mr. Bland: "Near the coast of Peru, about 45 miles from Iquique (the shipping port of guano) there is the chief deposite of nitrate of soda. The farmers, who collect and purify this natural product, carry it to the place of shipment, and always require to be paid in return with an equivalent quantity of guano, with which they manure their land, to the exclusion of the far cheaper nitrate of soda. We can not be surprised at this preference, when we learn that in the valley of Chancay, about 40 miles distant from Lima, the soil produces, when farmed with irrigation in the natural way, a return upon maize of only 15 for 1; whereas, with the aid of guano, it produces 500 for 1! Hence the Peruvian proverb: Huano, though no saint, works many miracles.

In the pamphlet recently published by Messrs. Gibbs and Myers, entitled "Peruvian and Bolivian Guano, its nature, properties, and results," we have a very interesting view of the best established facts with regard to its operation and effects upon every variety of soil, and in every variety of circumstance, as ascertained by the most intelligent agriculturists of the United Kingdom. The general conclusion that may be fairly deduced from the whole evidence is, that good guano will, under judicious application, increase the crops of grain, turnips, potatoes, and grass, by about 33 per cent.; and with its present price of 10*l*. per ton, at a cost considerably under the average cost of all other manures, whether farm-yard dung and composts, or artificial compounds. Guano is, moreover, peculiarly adapted to horticultural and floricultural improvement, by its relative cleanliness and facility of application.

The following observations upon guano, by Dr. Von Martius, of Munich, addressed to the agricultural society of Bavaria, deserve attention. Among animal manures, says he, it clearly claims the first place. It is uncommonly rich in ammoniacal salts, which act very favorable on vegetation. The ease with which these salts are decomposed, and exhale their ammonia into the air, is by him assigned as the reason why plants manured with guano generally present early in the morning accumulations of dew on the points of their leaves. The guano absorbs the atmospheric vapor, as well as carbonic acid; whereby it becomes so valuable a manure in dry barren regions. If we compare guano with other excrementitious manures, we shall find it far preferable to those afforded by man or other mammalia, which do not generally contain more than 20 per cent. of food that can be appropriated by plants. It is therefore five times better than night-soil, and also very superior to the French *poudrette*, which, being dried night-soil, loses, through putrefaction and evaporation, the greater proportion of its ammoniacal elements. In birds, the excretions both of the kidneys and intestines are contained in the cloaca; whereby the volatile elements of the former get combined with the more fixed components of the latter. The guano is also a richer manure, on account of its being produced by sea-fowl, which live entirely on fish, without admixture of vegetable matter. The exposure also of the guano as soon as deposited to the heat of a tropical sun, in a rainless climate, prevents the components from fermenting, and *mummifies* them, so to speak, immediately into a concrete substance not susceptible of decomposition till it gets moisture; whereas the dung of our dove-cotes suffers a considerable loss by exposure to our humid atmosphere. But in their action on vegetation, and in their chemical composition, these two bird excrements are analogous. Davy found in fresh dove-cote manure 23 parts in 100 soluble in water, which yielded abundance of carbonate of ammonia by distillation, and left carbonaceous matter, saline matter, principally common salt, and carbonate of lime as a residuum. Pigeons' dung readily ferments, but after fermentation afforded only 8 per cent. of soluble matter, which gave proportionably less carbonate of ammonia in distillation than the dung recently voided. Dr. Von Martius proceeds to compare the proportion of soluble salts in guano and pigeons' dung, and thinks that by that comparison alone he can establish the superiority of the former; but he should have considered that the insoluble urate of ammonia, which is so powerful and copious a constituent of good guano, and is present in much smaller proportion in pigeons' dung, is sufficient of itself to turn the balance greatly in favor of the Peruvian manure. His general estimate, however, that the manuring power of genuine guano is four times greater than that of pigeons' dung, is probably not wide of the truth. Besides the above-mentioned constituents, guano derives no small portion of its fertilizing virtue from the great store of phosphoric acid which it contains, in various states of saline combination, with lime, magnesia, and ammonia. Of all the principles furnished to plants by the soil, the phosphates are, according to Liebig, the most important. They afford, so to speak, the bones and sinews of vegetable bodies, while ammonia supplies them with their indispensable element, azote. Their carbon, hydrogen, and oxygen, are derived from the air and water. Those products of vegetation which are most nutritious to man and herbiverous animals, such as bread-corn, beans, peas, and lentils, contain the largest proportion of phosphates. The ashes of these vegetable substances afford no alkaline carbonates. A soil in which phosphates are not present, is totally incapable of producing the above cereals. Agreeably to these views, Liebig believes that the importation of 1 cwt. of guano is equivalent to the importation of 8 cwts. of wheat; so that 1 cwt. of that manure assumes, with due culture, the form of 8 cwts. of substantial food for man.

Since all these testimonies concur to place this remarkable excrementitious product in such high estimation, it becomes a paramount duty of the chemist to investigate its composition, and to discover certain means of distinguishing what may be termed the sound or normal state of guano, from the decomposed, decayed, and effete condition. The analysis by Fourcroy and Vauquelin of a sample of guano presented to them by Baron Von Humboldt, gave the following composition in 100 parts:—

Urate of ammonia - - - - - - -	9·0
Oxalate of ammonia - - - - - - -	10·6
Oxalate of lime - - . - - - -	7·0
Phosphate of ammonia - - - - - -	6·0
Phosphate of ammonia and magnesia - - - - -	2·6
Sulphate of potash - - - - - - -	5·5
———— soda - - - - - - -	3·3
Sal ammoniac - - - - - - - -	4·2
Phosphate of lime - - - - - - -	14·3
Clay and sand - - - - - . -	4·7
Water and organic matters - - - - - -	32·3

How different are these constituents from those assigned by Klaproth—a no less skilful analyst than the French chemists! and how much this difference shows not only the complexity of the substance, but its very variable nature!

The general results of an analysis by Professor Johnston, published in his paper on guano, in the 3d part of the 2d vol. of the Journal of the Royal Agricultural Society of England, are as follows:—

Ammonia - - - - - - - -	7·0
Uric acid - - - - - - - -	0·8
Water and carbonic and oxalic acids, &c., expelled by a red heat	51·5
Common salt, with a little sulphate and phosphate of soda -	11·4
Phosphate of lime, &c. - - - - -	29·3
	00·0

The specimen of guano represented by this analysis must have been far advanced in decomposition, as shown by the very scanty portion of uric acid; and must have been originally impure (*spurious?*) from the large proportion of common salt, of which I have not found above 4 or 5 per cent. in any of the genuine guanos which I have had occasion to analyze. In another sample, Professor Johnston found 44·4 of phosphate of lime, with a little phosphate of magnesia, and carbonate of lime. These results resemble, to a certain degree, those which I have obtained in analyzing several samples of Chilian and African guanos, especially in the predominance of the earthy phosphates. The proportion of ammonia which can be extracted by the action of hydrate of soda and quicklime, at an elevated temperature, is the surest criterion of the soundness of the guano; for by this process we obtain not only the *ready formed* ammonia, from its several saline compounds, but also the ammonia producible from its uric acid, and undefined animal matter. These two latter quantities have been hitherto too little regarded by most analysts, though they constitute the most durable fund of azote for the nutrition of plants. Uric acid, and urate of ammonia, which contains 10-11ths of uric acid, being both nearly insoluble in water, and fixed at ordinary temperatures, continue to give out progressively to plants in the soil, the azote, of which they contain fully one-third of their weight. Under the influence of oxygen and a certain temperature, uric acid passes through a very remarkable series of transformation; producing allantoin, urea, and oxalic acid, which eventually becomes carbonic acid. These changes are producible immediately by the action of boiling water and peroxide of lead. From these metamorphoses, we can readily understand how much oxalate of ammonia and of lime is reported in many analyses of guano, though none, I believe, is to be found in the normal state, as it is occasionally imported from the Chincha Islands and Bolivia; nor were any oxalates found in the dung of the gannet, as analyzed by Dr. Wollaston, or of the sea eagle, according to the following analysis of Coindet: ammonia, 9·21 per cent.; uric acid, 84·65; phosphate of lime, 6·13=100. The Peruvian sea-fowl, by feeding exclusively on fish, would seem to swallow a large proportion of earthy phosphates; since, in the purest guano that has come in my way, I have found these salts to amount to from 10 to 15 per cent.

Dr. Von Martius proposes to use the degree of solubility of the guano in water as a good criterion of its quality; but this is a most fallacious test. Sound guano contains from 15 to 25 per cent. of insoluble urate of ammonia; nearly as much undefined animal matter, along with from 15 to 20 of earthy phosphates, leaving no more than 50 or 55 per cent. of soluble matter, exclusive of moisture; whereas decayed guano yields often 60 or 70 per cent. of its weight to water, in consequence of the uric acid and animal matter being wasted away, and the large portion of moisture in it, the latter amounting very often to from 25 to 35 per cent. The good Peruvian guano does not lose more than from 7 to 9 per cent. by drying, even at a heat of 212° Fahr.; and this loss necessarily includes a little ammonia. Each analysis of guano executed for the information of the farmer should exhibit definitely and accurately to at least 1 per cent.:—

1. The proportion of *actual* ammonia.
2. The proportion of ammonia producible also from the uric acid and azotized animal matter present; and which may be called the *potential* ammonia. This is a most valuable product, which is, however, to be obtained only from well-preserved dry guano.
3. The proportion of uric acid, to which, if 1 10th of the weight be added, the quantity of urate of ammonia is given.
4. The proportion of the phosphates of lime and magnesia.
5. The proportion of fixed alkaline salts, distinguishing the potash from the soda salts; the former being more valuable, and less readily obtainable, than the latter can be by the use of common salt. Wheat, peas, rye, and potatoes, require for their successful cultivation, a soil containing alkaline salts, especially those of potash.
6. The proportion of sandy or other earthy matter, which, in genuine guano, carefully collected, never exceeds 2 per cent. and that is silica.
7. The proportion of water, separable by the heat of 212° F.

The farmer should never purchase guano except its composition in the preceding particulars be warranted by the analysis of a competent chemist. He should cork up in a bottle a half-pound sample of each kind of guano that he buys; and if his crop shall disappoint reasonable expectation, he should cause the samples to be analyzed; and should the result not correspond to the analysis exhibited at the sale, he is fairly entitled to damages for the loss of his labor, rent, crop, &c. The necessity of following this advice will appear on considering the delusive if not utterly false analyses, under which cargoes of guano have been too often sold. In a recent case which came under my cognizance, in consequence of having been employed professionally to analyze the identical cargo, I found the guano to be nearly rotten and effete; containing alto gether only 2½ per cent. of ammonia, ½ per cent. of urate of ammonia, nearly 9 of sea salt, 24 of water, and 45½ of earthy phosphates. Now, this large cargo, of many hundred tons, fetched a high price at a public sale, under the exhibition of the following analysis by a chemist of some note:—

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Urate of ammonia, ammoniacal salts, and decayed animal matter	17·4
Phosphate of lime, phosphate of magnesia, and oxalate of lime -	48·1
Fixed alkaline salts - - - - - - - - - -	10·8
Earthy and stony matter - - - - - - - - -	1·4
Moisture - - - - - - - - - - - -	22·3
	100·0

The purchasers, I was told by the broker, bought it readily under a conviction that the guano contained 17·4 of ammonia, though the proportion of ammonia is not stated, but merely mystified, and adroitly confounded with the decayed animal matter.

By the following hypothetical analysis, much guano has been well sold :—

"Bone earth, 35 ; lithic acid, &c., 15 ; carbonate of ammonia, 14 ; organic matter, 36 =100." I am quite certain that no sample of guano can contain 14 per cent. of carbonate of ammonia—a very volatile salt. We shall see presently the state of combination in which the ammonia exists. It may contain at the utmost 4 or 5 per cent. of the carbonate ; but such guano must have been acted upon powerfully by humidity, and will therefore contain little or no uric acid.

In the very elaborate examination of guano by T. Oellacher, apothecary at Innsbruck, published in a recent number of Buchner's *Repertorium of Pharmacy*, it is said, that if a glass rod dipped into muriatic acid be held over guano, strong fumes are developed; and the solution of guano has an alkaline reaction with litmus-paper. These phenomena evidently indicate the presence of carbonate of ammonia, and of course a partially decomposed guano ; for sound Chincha and Bolivian guanos have an *acid* reaction, proceeding from the predominance of phosphoric acid. Farmers frequently judge of the goodness of guano by the strength of the ammoniacal odor; but in this judgment they may egregiously err, for the soundest guano has no smell of ammonia whatever; and it begins to give out that smell only when it is more or less decomposed and wasted.

Oellacher could find no evidence of urea in his guano ; I have obtained fully 5 per cent. of this substance from good Peruvian guano.

I shall now describe my own system of analysis :—

1. In every case I determine, first of all, the specific gravity of the guano ; which I take by means of spirits of turpentine, with a peculiar instrument contrived to render the process easy and precise. If it exceeds 1·75 in density, water being 1·0, it must contain sandy impurities, or has an excess of earthy phosphates, and a defect of azotized animal matter.

2. I triturate and digest 200 grains of it with distilled water, filter, dry the insoluble matter, and weigh it.

3. The above solution, diffused in 2,000 gr. measures, is examined as to its specific gravity, and then with test paper, to see whether it be acid or alkaline.

4. One half of this solution is distilled along with slaked lime in a matrass connected with a small quintuple globe condenser, containing distilled water, and immersed in a basin of the same. As the condensing apparatus terminates in a water-trap, no part of the ammonia can be lost; and it is all afterward estimated by a peculiar meter, whose indications make manifest one hundredth part of a grain.

5. The other half of the solution is mixed with some nitric acid, and divided into 3 equal portions.

a, the first portion, is treated with nitrate of barytes, and the resulting sulphate of barytes is collected, ignited, and weighed.

b, the second portion, is treated with nitrate of silver, and the resulting chloride of silver ignited and weighed.

c, the third portion, has a certain measure of a definite solution of ferric nitrate mixed with it, and then ammonia in excess. From the weight of the precipitated subphosphate of iron after ignition, the known amount of oxide used being deducted, the quantity of phosphoric acid in the soluble portion of the guano becomes known.

d, the three above portions are now mixed, freed by a few drops of dilute sulphuric and hydrochloric acids from any barytes and silver left in them, and then tested by nitrate of lime for oxalate of ammonia. The quantity of oxalate of lime obtained, determines that point.

6. The last liquor filtered, being freed from any residuary particles of lime by oxalate of ammonia, is evaporated to dryness and ignited, to obtain the fixed alkaline matter. This being weighed, is then dissolved in a little water, neutralized with acid, and treated with soda-chloride of platinum. From the quantity of potash-chloride of platinum, which precipitates, after being filtered, dried, and weighed, the amount of potash present is deducted—the rest is soda. These bases may be assigned to the sulphuric, hydro-chloric, and phosphoric acids, in proportions corresponding to their respective affinities.

7. The proportion of organic matter in the above *solution* of guano, is determined directly by evaporating a certain portion of it to dryness, and igniting. The loss of

weight, minus the ammonia and oxalic acid, represents the amount of organic matter.

8. A second portion of a solution of the guano is evaporated to dryness by a gentle steam heat, weighed, enclosed in a stout well-closed phial along with alcohol of 0·825, and heated to 212°. After cooling, the alcoholic solution is decanted or filtered clear, evaporated to dryness by a gentle heat, and weighed. This is urea, which may be tested by its conversion into carbonate of ammonia, when heated in a test tube or small retort. In this way, I have obtained from Bolivian guano, 5 per cent. of urea; a certain proof of its entire soundness.

9. *Analysis of the insoluble matter.* One third of it is digested with heat in abundance of Borax-water, containing $\frac{1}{100}$ of the salt, filtered, and the filter dried by a steam heat. The loss of weight indicates the amount of uric acid, which is verified by supersaturating the filtrate with acetic or hydrochloric acid, thus precipitating the uric acid, throwing it upon a filter, drying, and weighing it. This weight should nearly agree with the above loss of weight, the small difference being due to soluble organic matter, sometimes called geine and ulmic acid. The uric acid is evidenced, 1, by its specific gravity, which I find to be only 1·25, as also that of the urate of ammonia; 2, by its affording fine purple *murexide* when heated in a capsule along with nitric acid, and then exposed to the vapor of ammonia from a feather held over it; 3, by its dissipation when heated, without emitting an empyreumatic odor.

10. Another third of the solid matter is distilled along with half its weight of slaked lime, and 10 times its weight of water, in the apparatus already described, and the ammonia obtained from it estimated.

11. The remaining third having been ignited, is digested with a gentle heat in weak hydrochloric acid, and the undissolved silica and alumina washed on a filter, dried, and weighed. To the hydrochloric solution, dilute sulphuric acid is added, and the mixture is heated till all the hydrochloric acid be expelled, with the greater part of the water. Alcohol of 0·850 is now poured upon the pasty residuum, and the whole, after being well stirred, is thrown upon a filter. The phosphoric acid passes through, as also the magnesia in union with sulphuric acid. The sulphate of lime, which is quite insoluble in spirits of wine, being washed with them, is dried, ignited, and weighed. From the weight of sulphate of lime, the quantity of phosphate of that earth, that was present, becomes known.

12. Ammonia in excess is now added to the filtrate, which throws down the granular phosphate of ammonia and magnesia. After washing and drying this powder at a heat of 150°, its weight denotes the quantity of that compound in the guano.

13. To the filtered liquor (of 12), if a little ammonia be added, and then muriate of magnesia be slowly dropped in, phosphate of ammonia and magnesia will precipitate, from the amount of which the quantity of phosphoric acid may be estimated.

14. The proportion of oxalate of lime is determined by igniting the washed residuum (of 9) and placing it in an apparatus for estimating the quantity of carbonic acid given off in dissolving carbonate of lime. The apparatus, either *fig.* 1 or 2, described in my little Treatise on Alkalimetry, will serve that purpose well. I have rarely obtained more than ½ gr. of carbonic acid from the insoluble residuum of 100 gr. of good guano, and that corresponds to less than 1½ per cent. of oxalate of lime in the guano. Sometimes no effervescence at all is to be perceived in treating the washed residuum with acid after ignition.

15. The carbonate of ammonia in guano is readily determined by filtering the solution of it in cold water, and neutralizing the ammonia with a test or alkalimetrical acid. (See the Treatise on Alkalimetry, above referred to.)

16. Besides the above series of operations, the following researches must be made to complete our knowledge of guano. The insoluble residuum (of 10) which has been deprived by two successive operations of its uric acid and ammonia, may contain azotized organic matter. It is to be therefore well dried, mixed with 5 times its weight of the usual mixture of hydrate of soda and quicklime, and subjected to gentle ignition in a glass or iron tube closed at one end, and connected at the other with an ammonia condensing apparatus. The amount of ammonia being estimated by a proper ammonia meter, represents the quantity of azote, allowing 14 of this element for 17 of ammonia, being the potential ammonia corresponding to the undefined animal matter. In a sample of Peruvian guano I obtained 5 per cent. of ammonia from this source.

17. The whole quantity of ammonia producible from guano is to be determined by gently igniting 25 gr. of it well dried, and mixed with ten times its weight of the mixture of hydrate of soda and quicklime (2 parts of the latter to 1 of the former). The ammonia disengaged is condensed and measured, as described above.

18. The ready-formed ammonia is in all cases determined by distilling a mixture of 100 gr. of it with 50 gr. of slaked lime, condensing the disengaged ammonia, and estimating it exactly by the meter.

19. The relation of the combustible and volatile to the incombustible and fixed constituents of guano, is determined by igniting 100 gr. of it in a poised platinum capsule.

The loss of weight denotes the amount of combustible and volatile matter, including the moisture, which is known from a previous experiment.

20. The insoluble matter is digested in hot water, thrown upon a filter, dried, and weighed. The loss of weight is due to the fixed alkaline salts, which, after concentrating their solutions, are investigated by appropriate tests: 1, nitrate of barytes for the sulphates; 2, nitrate of silver for the chlorides and sulphates; and 3, soda-chloride of platinum, for distinguishing the potash from the soda salts.

21. The insoluble matter (of 20) is digested with heat in dilute nitric or hydrochloric acid, and the whole thrown upon a filter. The silica which remains on the filter is washed, ignited, and weighed. The lime, magnesia, and phosphoric acid, may be determined as already pointed out.

22. I have endeavored to ascertain if muriate of ammonia be present in guano, by evaporating its watery solution to dryness, and subliming the residuum, but I have never obtained a satisfactory portion of sal ammoniac; and therefore I am inclined to think there is little of it. The quantity of chlorine to be obtained from guano is too inconsiderable to lead to a suspicion of its presence, except in combination with sodium and potassium. Phosphate of soda is also a doubtful product—but if present, it may be obtained from the saline matter (of 20), by acidulating it with nitric acid; precipitating first with nitrate of barytes, next with nitrate of silver, taking care to use no excess of these two re-agents, then supersaturating the residuum with ammonia, and adding acetate of magnesia, when the characteristic double phosphate of this earth should fall, in case phosphate of soda be present.

By the preceding train of researches, all the constituents of this complex product may be exactly disentangled and estimated; but they manifestly require much care, patience, time, and dexterity, and also a delicate balance, particularly in using the appropriate apparatus for generating the potential ammonia, and for measuring the whole of this volatile substance separated in the several steps of the process. It may be easily imagined how little confidence can be reposed in many of the analyses of guano, framed, I fear, too often with the view of promoting the sale of an indifferent or even spurious article of commerce.

A. I shall now give in detail my analytical results upon three different samples of a good South American guano; and next the general results upon three samples of African and Chilian guanos :—

I. Guano from Bolivia, imported by the Mary and Anne. This sample was taken by myself, as an average out of several bags in the lighter, before the cargo was landed. Pale yellow brown color, dry, partly pulverulent, partly concreted, in small lumps, with a few small fragments of granite interspersed, and which, being obvious, were separated prior to the analysis. Specific gravity of the pulverulent portion without the granite, 1.60; of the concretions, 1·66; mean 1·63. Water digested on the former portion is neutral to litmus, that on the latter is faintly acid.

2. 100 parts lose 6·5 by the heat of boiling water, and exhale no ammonia. When digested and triturated with cold water, 30·5 parts dissolve, and 69·5 are obtained after drying, at 212° F. Of those 30·5 parts, 6·5 are therefore water, easily separable, and 24·5 parts are solid matter.

3. 100 parts, mixed with 9 times their weight of water, and 50 of lime, being distilled in an alembic connected with the five-globe condenser, &c., afforded exactly 4·2 of ammonia. 20 grains in fine powder, along with 200 of a mixture, consisting of 2 parts of dry lime and 1 of hydrate of soda, were gently ignited in a combustion-tube connected with the ammonia-condensing apparatus, and they produced 4·25 grains of ammonia—equivalent to 21·25 from 100 grains of the guano. Thus only 4·2 per cent. of ammonia were ready formed; while 17·05 lurked, so to speak, in their azotized elements.

From its aspect, and its want of ammoniacal odor, this guano, the first cargo received from Bolivia, was imagined by the importers to be of bad quality; and, accordingly, my very favorable report of its analysis surprised them not a little, and rather unsettled the little faith they at that time (January, 1843) had in chemistry. But about a fortnight after the date of my report they received a letter from Peru, apprizing them of the excellence of that cargo of Bolivian guano, and of its being prized by the Americans, as possessing fertilizing powers in a pre-eminent degree. I consider this guano, therefore, as a type of the substance in its best state.

II. The *soluble* matter was analyzed, in the manner already detailed, and was found to consist of—

1.	Urea - - - - - -	5·00
2.	Sulphate of potash - - - -	7·90
3.	Chloride of sodium - - - -	5·00
4.	Biphosphate of ammonia - -	5·50
5.	Oxalate of ammonia - - -	0·60
		24·0

In these ammoniacal salts there are only 1·65 parts of ammonia; but I obtained 2·55 grains in distilling the soluble matter of 100 grains of the guano. The remaining 0·9 parts, therefore, must have proceeded from the partial decomposition of the urea during the long ebullition necessary to extract every particle of ammonia, in distilling the guano along with lime.

III. The *insoluble* matter =69·5 parts, was found to consist of—

1.	Silica	2·25
2.	Subphosphate of lime	9·00
3.	Phosphate of magnesia and ammonia	1·25
4.	Urate of ammonia	15·27
5.	Undefined azotized organic matter, affording, with the 14 parts of uric acid, by ignition with hydrate of soda, 17·05 parts of ammonia	41·73
		69·50

This result as to the large proportion of organic matter in the dried insoluble residuum was verified by igniting a given quantity of it, when it was found to lose, out of 69·5 parts, 57; corresponding to the 15·27 urate of ammonia, 41·73 of undefined organic matter, and 0·08 of ammonia, in the double magnesian phosphate. In the urate and double phosphate are 1·35 of ammonia, which, with the 2·55, make 3·9 parts; the other 0·3 parts may be traced to the urea.

As these results differ very considerably in many respects from those of the analyses made by respectable German chemists, I was careful to verify them by manifold variations of the process, as follows:—

1. The soluble matter, with *acid* reaction, of 100 parts of the *lumps* of the Bolivian guano, was examined by per-acetate of iron and ammonia, for phosphoric acid, and afforded 4 parts of it, which is more than had been found in the *neutral* pulverulent guano. After the phosphoric acid was separated by that method, chloride of calcium gave no cloud with the filtered liquor, proving that no oxalic acid was present in these nodules. The washed insoluble matter, when gently ignited, and treated with dilute nitric acid, afforded no effervescence whatever, and therefore showed that no oxalate of lime had been present, for it would have become a carbonate.

It is necessary to determine from time to time the quantity of ferric oxide in the acetate or nitrate, as it is liable to be deposited from the solution when this is kept for some time. If this point be not attended to, serious errors would be committed in the estimation of the phosphoric acid.

2. The quantity of uric acid was verified by several repetitions, and found to be 14 per cent.

3. The undefined organic matter, when deprived of the uric acid by prolonged digestion with weak borax, being subjected to ignition along with hydrate of soda, yielded the quantity of ammonia requisite to constitute the whole sum, that producible from the uric acid also being taken into account.

4. The little lumps of the guano afforded, by distillation along with quicklime, 5·27 per cent. of ready-formed ammonia, probably from the uric acid having been partially decomposed by the moisture which had caused them to concrete. It is a curious fact, that the solution of borax, from being of an alkaline, becomes of an acid reaction, after digestion with the Bolivian guano.

5. For distinguishing and separating the soda salts from those of potash, I tried the antimoniate of potash, according to Wackenroder's prescription, but I found reason to prefer very much the crystallized soda-chloride of platinum, for that purpose.

From another specimen of the Bolivian guano, I extracted 3·5 per ct. of the ammonia-phosphate of magnesia.

B. A sample of guano from the Chincha islands, of nearly the same light color as the preceding, and the same dryness, being an early importation of 250 tons in the present year, was subjected by me to a careful analysis.

1. The solution in water of this guano had an alkaline reaction from carbonate of ammonia, which, being neutralized by test acid, indicated 0·34 per cent. of ammonia, equivalent to about 1 of the smelling sesqui-carbonate.

2. Of this guano, 47 per cent. were soluble in water, and 53 per cent. remained, after drying at a heat of 212° F. Of the above 47 parts, 8·5 were moisture in the guano.

3. The solution being acidulated with nitric acid, was treated with acetate of barytes, in a quantity equivalent to the sulphuric acid present, and it afforded 12 parts of sulphate of barytes. With the filtered liquor, 700 water grain measures of ferric acetate were mixed, and then ammonia in excess; 18·5 parts of washed and ignited sub-phosphate of iron were obtained, from which deducting 8·8 parts present in the acetate, 9·7 remain as the quantity of phosphoric acid; but 9·7 of acid produce 13·25 of bi-phosphate of ammonia, which contain only 2·3 of ammonia, combined with 0·95 of water.

or its elements. From the alkaline excess in the guano, there can be no doubt, however, that it contained the sub-phosphate (*found in the urine of Carnivora*), and not the bi-phosphate of that base. In this case, 9·7 of acid produce 14·32 of dry saline compound, containing 4·62 of ammonia, which, with the 0·34 of ammonia in the carbonate, constitute a sum of 4·96. To the liquor freed from the phosphate of iron, and acidulated with nitric acid, acetate of lime being added, 3·33 parts of oxalate of this base were obtained, which are equivalent to 3·23 oxalate ammonia, containing 0·89 of ammonia.

4. Nitrate of silver now produced from the filtered residual solution 8 parts of chloride, corresponding to nearly 3 of sal ammoniac, which contain nearly 0·95 of ammonia.

5. The 53 parts insoluble in water were digested with weak solution of borax at a boiling heat, thrown on a filter, and the uric acid being precipitated from the filtrate by means of a little hydrochloric acid, washed and dried, was found to weigh 13·5 parts. There were left on the filter 36·5 parts, dried at 212° F., so that 3 parts of soluble organic matter had passed through the filter. These 36·5 parts lost by ignition only 9·7 parts in organic matter, became white, and afforded a very faint effervescence with hydro-chloric acid, showing that a very little oxalate of lime had been present. 1·25 parts of silica were left after the action of the acid. To the solution of the 26·55 parts, sulphuric acid was added, and the mixture being heated to expel the hydro-chloric acid and the excess of the sulphuric, the residuary matter was digested and washed with dilute alcohol, and thrown on a filter; the solution of magnesia passed through, while the sulphate of lime remained. After ignition, this weighed 27·5 parts, equivalent to 22 of sub-phosphate of lime. On supersaturating the filtrate with ammonia, 4·5 parts of the magnesian ammonia phosphate were precipitated, containing 0.32 of ammonia. With the 13·5 parts of uric acid, 1·23 of ammonia had been originally combined, forming 14·73 of urate.

6. 25 grains of the dry guano afforded, by ignition in the combustion-tube along with 200 grains of the mixed lime and hydrate of soda, 4·165 of ammonia, which correspond to 16·66 in 100 parts of the dry, or to 15·244 in the natural state; leaving therefore 5 parts for the quantity of potential ammonia, or of ammonia producible from the decomposition of its azotized organic matter. This guano is, therefore, well adapted to promote permanently the fertility of a soil. It yields besides to alcohol a notable quantity of urea, which I did not think it worth while to determine quantitively, and from which undoubtedly a portion of the ammonia proceeded, in the distillation with milk of lime.

7. 100 parts afforded by distillation with milk of lime, 10·2 of ammonia.

8. The total constituents of that guano, being tabulated, are—

I.	Matter soluble in water	47·00	
consisting of—			
			Ammonia.
1.	Sulphate of potash, with a little sulphate of soda	6·00	
2.	Muriate of ammonia	3·00	0.95
3.	Phosphate of ammonia	14·32	4·62
4.	Sesqui-carbonate of ammonia	1·00	0·34
5.	Sulphate of ammonia	2·00	0·50
6.	Oxalate of ammonia	3·23	0·89
7.	Water	8·50	
8.	Soluble organic matter and urea	8·95	
		47·00	
II.	Matter insoluble in water	53·00	
consisting of—			
1.	Silica	1·25	
2.	Undefined organic matter	9·52	
3.	Urate of ammonia	14·73	1·23
4.	Oxalate of lime	1·00 ?	
5.	Sub-phosphate of lime	22·00	
6.	Phosphate of magnesia and ammonia	4·50	0·32
		53·00	9·80

The remaining 1.25 of *actual* ammonia may be fairly traced to the partial decomposition of the urea during the distillation with lime; whereas the 5 per cent. of potential ammonia proceeded from the transforming decomposition of the uric acid.

C. *Foliated guano*, from Peru, in caked pieces, the layers very thin, parallel, and interspersed with white streaks. This guano was somewhat dense for a pure specimen, having a specific gravity of 1·7. The insoluble matter afforded by digestion with borax water, no less than 25·2 per ct. of pale yellow uric acid; 9 of other combustible organic matter, and 15 of earthy matter; consisting of silica, 3·5; phosphate of magnesia and ammonia, 6·5; and only 5 of sub-phosphate of lime or bone earth. It lost 10 per cent. when dried in a heat of 212° F. The remaining 30·8 parts soluble in water, had a strong acid reaction, and afforded, by ferric acetate and ammonia, 6 of phosphoric acid, equivalent to 9·7 of crystallized bi-phosphate of ammonia, after acetate of barytes had separated the sulphuric acid. No less than 17 parts of chloride of silver were obtained, by precipitating with nitrate of silver the liquor filtered from the phosphate of iron, and acidulated with nitric acid. As the present is an accidental sample, and not an average of any importation, I did not prosecute the research further.

D. *Chincha guano*, of a somewhat darker color than the preceding, and alkaline reaction; specific gravity, 1·62. Digested with water and strained, 56·75 parts remained after drying it at 212° F. The solution, evaporated and dried also at 212°, afforded 31·25 of saline matter. This saline mass being mixed with four fifths of its weight of slaked lime, nine times its weight of water, and distilled, afforded of ammonia 14·28 per cent. Some chemists have prescribed potash instead of lime, for separating the ammonia in distillation; but no person of intelligence who has made the experiment once will choose to repeat it, because the potash forms with the organic matter of the guano a viscid compound, that froths up like a mass of soap-bubbles, and coming over with the vapors, obstructs and vitiates the result.

2. When dried altogether by a steam heat, 100 parts lost 12 in moisture; whereas by evaporating and drying the soluble matter by itself, the loss amounted to 16·3, no doubt by the dissipation of some of the ammoniacal salts; for 100 parts of the entire guano afford, by distillation with quicklime, 9 parts of ammonia, and by the transforming decomposition with hydrate of soda and lime, 16·25, indicating 7·25 of *potential* ammonia, in addition to the 9 of ready formed. The insoluble matter of 100 parts afforded to borax-water a solution containing 16·5 of uric acid, corresponding to 18 of urate of ammonia. There remained on the filter, after drying it at 212° F., only 33·8 parts; so that about 5 parts of soluble organic matter had passed through the filter in the borax water. These 33·8 consisted of subphosphate of lime 17, magnesian phosphate of ammonia 5·5, silica 0·7, and combustible organic matter 10·6.

The ammonia in the soluble portion was in the state chiefly of phosphate; there was merely a faint trace of oxalate of ammonia.

E. *African Guano.*—Among the many samples of African guano which I have had occasion to analyze for the importers, none has contained any appreciable quantity of uric acid, or by consequence of potential ammonia. The best afforded me 10 per cent. of ready-formed ammonia, existing chiefly in the state of a phosphate, though they all contain carbonate of ammonia, and have of consequence an alkaline reaction. The said sample contained 21·5 of moisture, separable by a heat of 212° F. Its specific gravity was so low as 1·57, in consequence of the large proportion of moisture in it. It contained 23 per cent. of subphosphate of lime, 3 of magnesian phosphate of ammonia, 1 of silica, and 1·5 of alkaline sulphate and muriate. The remaining 50 parts consisted of decayed organic matter, with phosphate of ammonia, and a little carbonate, equivalent to half a grain of ammonia, which is the largest quantity in such guanos. Other African guanos have afforded from 24 to 36 of moisture, no uric acid; no potential ammonia; but decayed organic matter; from 5 to 7 of ready-formed ammonia in the state of phosphate, with a little carbonate; from 25 to 35 per cent. of subphosphate of lime; 5 or 6 of the magnesian phosphate of ammonia; more or less oxalates from the decomposition of the uric acid, and 3 to 5 per cent. of fixed alkaline salts.

F. The *Chilian Guano* gathered on the coast, already adverted to, contained a remarkable proportion of common salt, derived probably from the sea spray.

The following is the general report of the chemical examination of several samples of guano, which I made for Messrs. Gibbs of London, and Messrs. Myers of Liverpool:—

"In these various analyses, performed with the greatest care, and with the aid of the most complete apparatus for both inorganic and organic analysis, my attention has been directed, not only to the constituents of the guano which act as an immediate manure, but to those which are admitted by practical farmers to impart durable fertility to the grounds. The admirable researches of Professor Liebig have demonstrated that AZOTE, the indispensable element of the nourishment of plants, and especially of wheat and others abounding in gluten (an azotized product), must be presented to them in the state of *ammonia*, yet not altogether ammonia in the pure or saline form, for, as such, it is too readily evaporated or washed away; but in the dormant, or as one may say, in the *potential* condition in contradistinction from the *actual*. Genuine Peruvian and Bolivian guanos, like those which I have minutely analyzed, surpass very far all other species of manure, whether natural or artificial, in the quantity of *potential* ammonia, and, therefore, in the permanency of their action upon the roots of plants, while, in consequence of the ample store of *actual* ammonia which they contain ready formed, they are qualified to give immediate vigor to vegetation. Urate of ammonia constitutes a considerable portion of the azotized organic matter in well-preserved guano; it is nearly insoluble in water, not at all volatile, and is capable of yielding to the soil, by its slow decomposition, nearly one third of its weight of ammonia. No other manure can rival this animal saline compound. One of the said samples of guano afforded me no less than 17 per cent. of potential ammonia, besides 4½ per cent. of the actual or ready formed; others from 7 to 8 per cent. of ammonia in each of these states respectively. These guanos which I have examined are the mere excrement of birds, and are quite free from the sand, earth, clay, and common salt, reported in the analyses of some guanos, and one of which (sand) to the amount of 30 per cent. I found myself in a sample of guano from Chile.

"The Peruvian guano, moreover, contains from 10 to 25 per cent. of phosphate of lime, the same substance as bone-earth, but elaborated by the birds into a pulpy consistence, which, while it continues insoluble in water, has been thereby rendered more readily absorbable and digestible (so to speak) by the roots of plants. I have therefore no doubt, that by the judicious application of these genuine guanos, mixed with twice or thrice their weight of a marly or calcareous soil, to convert their phosphate of ammonia into phosphate of lime and carbonate of ammonia, as also to dilute all their ammoniacal compounds—such crops will be produced, even on sterile lands, as the farmer has never raised upon the most improved soil by the best ordinary manure. To the West India planter, guano will prove the greatest boon, since it condenses in a portable and inoffensive shape the means of restoring fertility to his exhausted cane fields, a benefit it has long conferred on the poorest districts of Peru.

"I respectfully observe, that no analysis of guano hitherto made public at all exhibits the value of the cargoes referred to above, while none gives the quantity of ammonia dormant in the azotized animal matter of the birds' dung, which, called into activity with the seeds in the soil, becomes the most valuable of its constituents, as a source of perennial fertility. In the detailed account of my analyses of this complex excretion (now preparing for publication), all the above statements will be brought within the scope of general comprehension. I shall also describe my 'ammonia generator,' based on the process invented in the laboratory of Professor Liebig, and also my 'ammonia meter,' which, together, can detect and measure one hundredth part of a grain weight of absolute ammonia, whether potential or actual, in any sample of guano.

"Meanwhile the following may be offered as the average result of my analyses of genuine guano in reference to its agricultural value :—

"1. Azotized animal matter, including urate of ammonia, together capable of affording from 8 to 16 per cent. of ammonia by slow decomposition in the soil	50
2. Water	8 to 11
3. Phosphate of lime	12 to 25
4. Phosphate of ammonia, sulphate of ammonia, ammonia-phosphate of magnesia, together containing from 5 to 9 parts of ammonia	13
5. Siliceous sand	1
	100

"Very moist guano has in general more actual and less potential ammonia than the dry guano.

"Andrew Ure.

"*London*, 13 *Charlotte street, Bedford square,*
"*February* 14, 1843."

Oellacher's analysis of a brownish yellow guano is as follows [see top of next page] :—

I am satisfied from its large proportion of oxalate of ammonia, that the sample thus analyzed was by no means a fair or normal specimen of guano; and it is in fact widely different from all the fresh samples which have passed through my hands. It is described as "knobby, being mixed with light laminated crystalline portions, in white grains, from the size of a pea to that of a pigeon's egg." Having some lumpy concretions of a similar aspect in my possession, I submitted them to chemical examination.

G. 1,000 grains being digested in boiling water and strained, afforded a nearly colorless solution. This was concentrated till crystals of oxalate of ammonia appeared. It was then acidulated with hydrochloric acid, to protect the phosphoric acid from precipitation, and next treated carefully with a solution of nitrate of lime equivalent to the oxalic acid present. The oxalate of lime thus obtained being converted into carbonate weighed 80·5 grains, corresponding to 100 of oxalate of ammonia, being 10 per cent. of the weight of the guano.

			Ammonia.
1.	Urate of ammonia	12·20	1·06
2.	Oxalate of ammonia	17·73	6·50
3.	Oxalate of lime	1·30	
4.	Phosphate of ammonia	6·90	1·79
5.	Phosphate of ammonia and magnesia	11·63	1·68
6.	Phosphate of lime	20·16	
7.	Muriate of ammonia	2·25	0·72
8.	Chloride of sodium (common salt)	0·40	
9.	Carbonate of ammonia	0·80	0·23
10.	Carbonate of lime	1·65	
11.	Sulphate of potash	4·00	
12.	Sulphate of soda	4·92	
13.	Humate of ammonia	1·06	0·09
14.	Substance resembling wax	0·75	
15.	Sand	1·68	
16.	Water (hygroscopic)	4·31	
17.	Undefined organic matter	8·26	
		100·00	12·07

The liquor filtered from the oxalate was precipitated by nitrate of barytes, and afforded 112 grains of sulphate of barytes = 38 sulphuric acid; and the last filtrate being mixed with a given measure of ferric acetate, and the mixture supersaturated with ammonia, yielded subphosphate of iron, equivalent to 5 per cent of phosphoric acid. I digested with heat other 500 grains of the same guano in a weak solution of borax, filtered, acidulated the liquid, but obtained merely a trace of uric acid. It is clear therefore that the oxalate of ammonia had been formed in this guano at the expense of the uric acid, and that its concreted state, and the crystalline nodules disseminated through it, were the result of transformation by moisture in a hot climate, which had agglomerated it to a density of 1·75; whereas clean fresh guano, friable and dry like the above, is seldom denser than 1·65. The guano contained only 3·23 of ammonia; 65 of insoluble matter, 53 of earthy phosphates, 5 silica, 3 alkaline salts (fixed), and 7 organic matter.

Oxalate of ammonia, being readily washed away, it is a bad substitute for the urate of ammonia, urea, and azotized animal matter, which it has replaced. Oellacher could find no urea in the guano which he analyzed; another proof of its disintegration.

Bartel's analysis of a brown-red guano is as follows:—

1.	Muriate of ammonia	6·500
2.	Oxalate of ammonia	13·351
3.	Urate of ammonia	3·244
4.	Phosphate of ammonia	6·450
5.	Substances resembling wax and resin	[illegible]·600
6.	Sulphate of potash	4·277
7.	Sulphate of soda	1·119
8.	Phosphate of soda	5·291
9.	Phosphate of lime	9·940
10.	Phosphate of ammonia and magnesia	4·196
11.	Common salt	0·100
12.	Oxalate of lime	16·360
13.	Alumina	0·104
14.	Sand insoluble in nitric acid, and iron	5·800
15.	Loss (water and volatile ammonia and undefined organic matter)	22·718
		100·000

Voelckel, in his analysis of guano, states 7 per cent. of oxalate of lime—a result quite at variance with all my experience—for I have never found so much as 2 per cent. of carbonate of lime in the washed and gently ignited insoluble matter; whereas, according to Bartels and Voelckel, from 10 to 5 per cent. of carbonate should be obtained, as the equivalents of the proportions of the oxalate assigned by them.

All these analyses are defective moreover in not showing the total quantity of ammonia which the guano is capable of giving out in the soil; and since it appears that the freshest guano abounds most in what I have called *potential* ammonia, it must possess of consequence, the greatest fertilizing virtue.

A sample of *decayed dark-brown* moist guano from Chile, being examined as above described, for oxalate of ammonia, was found to contain none whatever; and it contained less than 1 per cent. of uric acid.

H. An article offered to the public, by advertisement, as Peruvian guano, was lately sent to me for analysis. I found it to be a spurious composition; it consisted of—

1.	Common salt	32·0
2.	Common siliceous sand	28·0
3.	Sulphate of iron or copperas	5·2
4.	Phosphate of lime	4·0, with
5.	Organic matter from bad guano, &c. (to give it smell)	23·3
6.	Moisture	7·5
		100·0

Genuine guano, when burned upon a red hot shovel, leaves a white ash of phosphate of lime and magnesia; whereas this factitious substance left a black fused mass of sea salt, copperas, and sand. The specific gravity of good fresh guano is seldom more than 1·66, water being 100; whereas that of the said substance was so high as 2·17 produced by the salt, sand, and copperas.

GUM (*Gomme*, Fr.; *Gummi*, *Pflanzenschleim*, Germ.) is the name of a proximate vegetable product, which forms with water a slimy solution, but is insoluble in alcohol, ether, and oils; it is converted by strong sulphuric acid into oxalic and mucic acids.

There are six varieties of gum: 1. gum arabic; 2. gum senegal; 3 gum of the cherry and other stone fruit trees: 4. gum tragacanth; 5. gum of Bassora; 6. the gum of seeds and roots. The first five spontaneously flow from the branches and trunks of their trees, and sometimes from the fruits, in the form of a mucilage which dries and hardens in the air. The sixth kind is extracted by boiling water.

Gum arabic and gum senegal consist almost wholly of the purest gum called *arabine* by the French chemists; our native fruit trees contain some *cerasine*, along with arabine; the gum of Bassora and gum tragacanth consist of arabine and bassorine.

Gum arabic flows from the *acacia arabica*, and the *acacia vera*, which grow upon the banks of the Nile and in Arabia. It occurs in commerce in the form of small pieces, rounded upon one side and hollow upon the other. It is transparent, without smell, brittle, easy to pulverize, sometimes colorless, sometimes with a yellow or brownish tint. It may be bleached by exposure to the air and the sun-beams, at the temperature of boiling water. Its specific gravity is 1·355. Moistened gum arabic reddens litmus paper, owing to the presence of a little supermalate of lime, which may be removed by boiling alcohol; it shows also traces of the chlorides of potassium and calcium, and the acetate of potash. 100 parts of good gum contain 70·40 of arabine, 17·60 of water, with a few per cents. of saline and earthy matters. Gum arabic is used in medicine, as also to give lustre to crapes and other silk stuffs.

Gum senegal is collected by the negroes during the month of November, from the *acacia senegal*, a tree 18 or 20 feet high. It comes to us in pieces about the size of a partridge egg, but sometimes larger, with a hollow centre. Its specific gravity is 1·436. It consists of 81·10 arabine; 16·10 water; and from 2 to 3 of saline matters. The chemical properties and uses of this gum are the same as those of gum arabic. It is much employed in calico-printing.

Cherry-tree gum consists of 52·10 arabine; 54·90 cerasine; 12 water; and 1 saline matter.

Gum tragacanth is gathered about the end of June, from the *astragalus tragacantha* of Crete and the surrounding islands. It has the appearance of twisted ribands; is white or reddish; nearly opaque, and a little ductile. It is difficult to pulverize, without heating the mortar. Its specific gravity is 1·384. When plunged in water, it dissolves in part, swells considerably, and forms a very thick mucilage. 100 parts of it consist of 53·30 arabine; 33·30 bassorine and starch; 11·0 water; and from 2 to 3 parts of saline matters. It is employed in calico printing, and by shoemakers.

Gum of Bassora; see BASSORINE.

Gum of seeds, as linseed, consists of 52·70 arabine; 28·9 of an insoluble matter; 10·3 water; and 7·11 saline matter. Neither bassorine nor cerasine seems to be present in seeds and roots. For *British Gum*, see STARCH.

GUM RESINS. (*Gomme-résines*, Fr.; *Schleimharze*, Germ.) When incisions are made in the stems, branches, and roots of certain plants, a milky juice exudes, which gradually hardens in the air; and appears to be formed of resin and essential oil, held suspended in water charged with gum, and sometimes with other vegetable matters, such as caoutchouc, bassorine, starch, wax, and several saline matters. The said concrete juice is called a gum-resin; an improper name, as it gives a false idea of the nature of the substance. They are all solid; heavier than water; in general opaque and brittle;

many have an acrid taste, and a strong smell; their colour is very variable. They are partially soluble in water, and also in alcohol; and the solution in the former liquid seldom becomes transparent. Almost all the gum resins are medicinal substances, and little employed in the arts and manufactures. The following is a list of them: assafœtida; gum ammoniac; bdellium; euphorbium; galbanum; gamboge; myrrh; olibanum or frankincense; opoponax; and scammony. Some of these are described in this work under their peculiar names.

GUMS. Under the generic name Gum several substances have been classed, which differ essentially, though they possess the following properties in common; viz. forming a thick mucilaginous liquid with water, and being precipitable from that solution by alcohol. Properly speaking, we should style gums only such substances as are transformed into mucic acid by nitric acid; of which bodies there are three: 1. *Arabine*, which constitutes almost the whole of gum arabic; 2. *Bassorine*, which forms the chief part of gum tragacanth; and 3. *Cerasine*, which occurs in cherry-tree gum, and is convertible into gum arabic by hot water.

1. Gum arabic, in its ordinary state, contains 17 per cent. of water, separable from it by a heat of 212° Fahr.

2. Cherry-tree gum consists of 52 per cent. of arabine, and 35 of a peculiar gum, which has been called *Cerasine*. This latter substance is convertible into grape sugar by boiling it with very dilute sulphuric acid.

GUNPOWDER. The following memoir upon this subject was published by me in the Journal of the Royal Institution for October, 1830. It contains the results of several careful analytical experiments, as also of observations made at the Royal Gunpowder Works at Waltham Abbey, and at some similar establishments in the neighbourhood of London.

Gunpowder is a mechanical combination of nitre, sulphur, and charcoal; deriving the intensity of its explosiveness from the purity of its constituents, the proportion in which they are mixed, and the intimacy of the admixture.

1. *On the nitre.*—Nitre may be readily purified, by solution in water and crystallization, from the muddy particles and foreign salts with which it is usually contaminated. In a saturated aqueous solution of nitre, boiling hot, the temperature is 240° F.; and the relation of the salt to its solvent is in weight as three to one, by my experiments: not five to one, as MM. Bottée and Riffault have stated. We must not, however, adopt the general language of chemists, and say that three parts of nitre are soluble in one of boiling water, since the liquid has a much higher heat and greater solvent power than this expression implies.

Water at 60° dissolves only one fourth of its weight of nitre; or, more exactly, this saturated solution contains 21 per cent. of salt. Its specific gravity is 1·1415; 100 parts in volume of the two constituents occupy now 97·91 parts. From these data we may perceive that little advantage could be gained in refining crude nitre, by making a boiling-hot saturated solution of it; since on cooling, the whole would concrete into a moist saline mass, consisting by weight of 2¾ parts of salt, mixed with 1 part of water, holding ¼ of salt in solution, and in bulk of 1⅞ of salt, with about 1 of liquid; for the specific gravity of nitre is 2·005, or very nearly the double of water. It is better, therefore, to use equal weights of saltpetre and water in making the boiling-hot solution. When the filtered liquid is allowed to cool slowly, somewhat less than three fourths of the nitre will separate in regular crystals; while the foreign salts that were present will remain with fully one fourth of nitre in the mother liquor. On redissolving these crystals with heat, in about two thirds of their weight of water, a solution will result, from which crystalline nitre, fit for every purpose, will concrete on cooling.

As the principal saline impurity of saltpetre is muriate of soda (a substance scarcely more soluble in hot than in cold water), a ready mode thence arises of separating that salt from the nitre in mother waters that contain them in nearly equal proportion. Place an iron ladle or basin, perforated with small holes, on the bottom of the boiler in which the solution is concentrating. The muriate, as it separates by the evaporation of the water, will fall down and fill the basin, and may be removed from time to time. When small needles of nitre begin to appear, the solution must be run off into the crystallizing cooler, in which moderately pure nitre will be obtained, to be refined by another similar operation.

At the Waltham Abbey gunpowder works the nitre is rendered so pure by successive solutions and crystallizations, that it causes no opalescence in a solution of nitrate of silver. Such crystals are dried, fused in an iron pot at a temperature of from 500° to 600° F., and cast into moulds. The cakes are preserved in casks.

About the period of 1794 and 1795, under the pressure of the first wars of their revolution, the French chemists employed by the government contrived an expeditious, economical, and sufficiently effective mode of purifying their nitre. It must be observed that this salt, as brought to the gunpowder-works in France, is in general a much cruder article than that imported into this country from India. It is extracted from the nitrous salts contained in the mortar-rubbish of old buildings, especially those of the lowest and filthiest descriptions. By their former methods, the French could not refine their nitre in less time than eight or ten days; and the salt was obtained in great lumps, very difficult to dry and divide; whereas the new process was so easy and so quick, that in less than twenty-four hours, at one period of pressure, the crude saltpetre was converted into a pure salt, brought to perfect dryness, and in such a state of extreme division as to supersede the operations of grinding and sifting, whence also considerable waste was avoided.

The following is a brief outline of this method, with certain improvements, as now practised in the establishment of the *Administration des poudres et saltpêtres*, in France.

The refining boiler is charged over night with 600 kilogrammes of water, and 120C kilogrammes of saltpetre, as delivered by the salpêtriers. No more fire is applied than is adequate to effect the solution of this first charge of saltpetre. It may here be observed, that such an article contains several deliquescent salts, and is much more soluble than pure nitre. On the morrow morning the fire is increased, and the boiler is charged at different intervals with fresh doses of saltpetre, till the whole amounts to 3000 kilogrammes. During these additions, care is taken to stir the liquid very diligently, and tc skim off the froth as it rises. When it has been for some time in ebullition, and when it may be presumed that the solution of the nitrous salts is effected, the muriate of soda is scooped out from the bottom of the boiler, and certain affusions or inspersions of cold water are made into the pot, to quicken the precipitation of that portion which the boiling motion may have kept afloat. When no more is found to fall, one kilogramme of Flanders glue, dissolved in a sufficient quantity of hot water, is poured into the boiler; the mixture is thoroughly worked together, the froth being skimmed off, with several successive inspersions of cold water, till 400 additional kilogrammes have been introduced, constituting altogether 1000 kilogrammes.

When the refining liquor affords no more froth, and is grown perfectly clear, all manipulation must cease. The fire is withdrawn, with the exception of a mere kindling, so as to maintain the temperature till the next morning at about 88° C. = 190·4 F.

This liquor is now transferred by hand-basins into the crystallizing reservoirs, taking care to disturb the solution as little as possible, and to leave untouched the impure matter at the bottom. The contents of the long crystallizing cisterns are stirred backwards and forwards with wooden paddles, in order to quicken the cooling, and the consequent precipitation of the nitre in minute crystals. These are raked, as soon as they fall, to the upper end of the doubly-inclined bottom of the crystallizer, and thence removed to the washing chests or boxes. By the incessant agitation of the liquor, no large crystals of nitre can possibly form. When the temperature has fallen to within 7° or 8° F., of the apartment, that is, after seven or eight hours, all the saltpetre that it can yield will have been obtained. By means of the double inward slope given to the crystallizer, the supernatant liquid is collected in the middle of the breadth, and may be easily laded out.

The saltpetre is shovelled out of the crystallizer into the washing chests, and heaped up in them so as to stand about six or seven inches above their upper edges, in order to allow for the subsidence which it must experience in the washing process. Each of these chests being thus filled, and their bottom holes being closed with plugs, the salt is besprinkled from the rose of a watering-can, with successive quantities of water saturated with saltpetre, and also with pure water, till the liquor, when allowed to run off, indicates by the hydrometer, a saturated solution. The water of each sprinkling ought to remain on the salt for two or three hours; and then it may be suffered to drain off through the plug-holes below, for about an hour.

All the liquor of drainage from the first watering, as well as a portion of the second, is set aside, as being considerably loaded with the foreign salts of the nitre, in order to be evaporated in the sequel with the mother waters. The last portions are preserved, because they contain almost nothing but nitre, and may therefore serve to wash another dose of that salt. It has been proved by experience, that the quantity of water employed in washing need never exceed thirty-six sprinklings in the whole, composed of three waterings, of which the first two consist of fifteen, and the last of six pots = 3 gallons E.; or in other words, of fifteen sprinklings of water saturated with saltpetre, and twenty-one of pure water.

The saltpetre, after remaining five or six days in the washing chests, is transported into the drying reservoirs, heated by the flue of the nearest boiler; here it is stirred up from time to time with wooden shovels, to prevent its adhering to the bottom, or running into lumps, as well as to quicken the drying process. In the course of about four hours, it gets completely dry, in which state it no longer sticks to the shovel, but falls down into a soft powder by pressure in the hand, and is perfectly white and pulverulent. It is now

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passed through a brass sieve, to separate any small lumps or foreign particles accidentally present, and is then packed up in bags or barrels. Even in the shortest winter days, the drying basin may be twice charged, so as to dry 700 or 800 kilogrammes. By this operation, the nett produce of 3000 kilogrammes (3 tons) thus refined, amounts to from 1750 to 1800 kilogrammes of very pure nitre, quite ready for the manufacture of gunpowder.

The mother waters are next concentrated; but into their management it is needless to enter in this memoir.

On reviewing the above process as practised at present, it is obvious that, to meet the revolutionary crisis, its conductors must have shortened it greatly, and have been content with a brief period of drainage.

2. *On the sulphur.*—The sulphur now imported into this country, from the volcanic districts of Sicily and Italy, for our manufactories of sulphuric acid, is much purer than the sulphur obtained by artificial heat from any varieties of pyrites, and may, therefore, by simple processes, be rendered a fit constituent of the best gunpowder. As it is not my purpose here to repeat what may be found in common chemical compilations, I shall say nothing of the sublimation of sulphur; a process, moreover, much too wasteful for the gunpowder-maker.

Sulphur may be most easily analyzed, even by the manufacturer himself; for I find it to be soluble in one tenth of its weight of boiling oil of turpentine, at 316° Fahrenheit, forming a solution which remains clear at 180°. As it cools to the atmospheric temperature, beautiful crystalline needles form, which may be washed sufficiently with cold alcohol, or even tepid water. The usual impurities of the sulphur, which are carbonate and sulphate of zinc, oxyde and sulphuret of iron, sulphuret of arsenic and silica, will remain unaffected by the volatile oil, and may be separately eliminated by the curious, though such separation is of little practical importance.

Two modes of refining sulphur for the gunpowder works have been employed; the first is by fusion, the second by distillation. Since the combustible solid becomes as limpid as water, at the temperature of about 230° Fahrenheit, a ready mode offers of removing at once its denser and lighter impurities, by subsidence and skimming. But I may take the liberty of observing, that the French melting pot, as described in the elaborate work of MM. Bottée and Riffault, is singularly ill-contrived, for the fire is kindled right under it, and plays on its bottom. Now a pot for subsidence ought to be cold set; that is, should have its bottom part imbedded in clay or mortar for four or six inches up the side, and be exposed to the circulating flame of the fire only round its middle zone. This arrangement is adopted in many of our great chemical works, and is found to be very advantageous. With such a boiler, judiciously heated, I believe that crude sulphur might be made remarkably pure; whereas by directing the heat against the bottom of the vessel, the crudities are tossed up, and incorporated with the mass. See EVAPORATION.

The sulphur of commerce occurs in three prevailing colors; lemon yellow verging on green, dark yellow, and brown yellow. As these different shades result from the different degrees of heat to which it has been exposed in its original extraction on the great scale, we may thereby judge to what point it may still be heated anew in the refinery melting. Whatever be the actual shade of the crude article, the art of the refiner consists in regulating the heat, so that after the operation it may possess a brilliant yellow hue, inclining somewhat to green.

In seeking to accomplish this purpose, the sulphur should first be sorted according to its shades; and if a greenish variety is to be purified, since this kind has been but little heated in its extraction, the fusion may be urged pretty smartly, or the fire may be kept up till everything is melted but the uppermost layer.

Sulphur of a strong yellow tinge cannot bear so great a heat, and therefore the fire must be withdrawn whenever three fourths of the whole mass have been melted.

Brown-colored brimstone, having been already somewhat scorched, should be heated as little as possible, and the fire may be removed as soon as one half of the mass is fused.

Instead of melting, separately, sulphurs of different shades, we shall obtain a better result by first filling up the pot to half its capacity, with the greenish-colored article, putting over this layer one quarter volume of the deep yellow, and filling it to the brim with the brown-colored. The fire must be extinguished as soon as the yellow is fused. The pot must then be closely covered for some time; after which the lighter impurities will be found on the surface in a black froth, which is skimmed off, and the heavier ones sink to the bottom. The sulphur itself must be left in the pot for ten or twelve hours, after which it is laded out into the crystallizing boxes or casks.

Distillation affords a more complete and very economical means of purifying sulphur, which was first introduced into the French gunpowder establishments, when their importation of the best Italian and Sicilian sulphur was obstructed by the British navy. Here the sulphur need not come over slowly in a rare vapor, and be deposited in a pulverulent form called flowers; for the only object of the refiner is to bring over the whole of the pure sulphur into his condensing chamber, and to leave all its crudities in the body of the still. Hence a strong fire is applied to elevate a denser mass of vapors, of a yellowish color, which passing over into the condenser, are deposited in a liquid state on its bottom, whilst only a few lighter particles attach themselves to the upper and lateral surfaces. The refiner must therefore give to the heat in this operation very considerable intensity; and, at some height above the edge of the boiler, he should provide an inclined plane, which may let the first ebullition of the sulphur overflow into a safety recipient. The condensing chamber should be hot enough to maintain the distilled sulphur in a fluid state—an object most readily procured by leading the pipes of several distilling pots into it; while the continuity of the operations is secured, by charging each of the stills alternately, or in succession. The heat of the receiver must be never so high as to bring the sulphur to a sirupy consistence, whereby its color is darkened.

In the sublimation of sulphur, a pot containing about 4 cwts. can be worked off only once in twenty-four hours, from the requisite moderation of its temperature, and the precaution of an inclined plane, which restores to it the accidental ebullitions. But, by distillation, a pot containing fully ten cwts. may complete one process in nine hours at most, with a very considerable saving of fuel. In the former plan of procedure, an interval must elapse between the successive charges; but in the latter, the operation must be continuous to prevent the apparatus from getting cooled; in sublimation, moreover, where communication of atmospheric air to the condensing chamber is indispensable, explosive combustions of the sulphurous vapors frequently occur, with a copious production of sulphurous acid, and correspondent waste of the sulphur; disadvantages from which the distillatory process is in a great measure exempt.

I shall here describe briefly the form and dimensions of the distilling apparatus employed at Marseilles in purifying sulphur for the national gunpowder works, which was found adequate to supply the wants of Napoleon's great empire. This apparatus consists of only two still-pots of cast iron, formed like the large end of an egg, each about three feet in diameter, two feet deep, and nearly half an inch thick at the bottom, but much thinner above, with a horizontal ledge four inches broad. A pot of good cast iron is capable of distilling 1000 tons of sulphur before it is rendered unserviceable, by the action of the brimstone on its substance, aided by a strong red heat. The pot is covered in with a sloping roof of masonry, the upper end of which abuts on the brickwork of the vaulted dome of condensation. A large door is formed in the masonry in front of the mouth of the pot, through which it is charged and cleared out; and between the roof-space over the pot, and the cavity of the vault, a large passage is opened. At the back of the pot a stone step is raised to prevent the sulphur boiling over into the condenser. The vault is about ten feet wide within, and fourteen feet from the bottom up to the middle of the dome, which is perforated, and carries a chimney about twelve feet high, and twelve feet diameter inside.

As the dome is exposed to the expansive force of a strong heat, and to a very considerable pressure of gases and vapors, it must possess great solidity, and be therefore bound with iron straps. Between the still and the contiguous wall of the condensing chamber, a space must be left for the circulation of air; a precaution found by experience indispensable; for the contact of the furnaces would produce on the wall of the chamber such a heat as to make it crack and form crevices for the liquid sulphur to escape. The sides of the chamber are constructed of solid masonry, forty inches thick, surmounted by a brick dome, covered with a layer of stones. The floor is paved with tiles, and the walls are lined with them up to the springing of the dome; a square hole being left in one side, furnished with a strong iron door, at which the liquid sulphur is drawn off at proper intervals. In the roof of the vault are two valve-holes covered with light plates of sheet-iron, which turn freely on hinges at one end, so as to give way readily to any sudden expansion from within, and thus prevent dangerous explosions.

As the chamber of condensation is an oblong square, terminating upwards in an oblong vault, it consists of a parallelopiped below, and semi-cylinder above, having the following dimensions:—

Length of the parallelopiped	16½ feet
Width	$10\frac{4}{5}$
Height	$7\frac{1}{4}$
Radius of the cylinder	$5\frac{2}{5}$
Height or length of semi-cylinder . . .	16½

Whenever the workman has introduced into each pot its charge of ten or twelve hundred weight of crude sulphur, he closes the charging doors carefully with their iron plates and cross-bars, and lutes them tight with loam. He then kindles his fire, and makes the sulphur boil. One of his first duties (and the least neglect in its discharge may occasion serious accidents) is to inspect the roof-valves and to clean them, so that they may play freely and give way to any expulsive force from within. By means of a cord and chain, connected with a crank attached to the valves, he can, from time to time, ascertain their state, without mounting on the roof. It is found proper to work one of the pots a certain time before fire is applied to the other. The more steadily vapors of sulphur are seen to issue from the valves, the less atmospherical air can exist in the chamber, and therefore the less danger there is of combustion. But if the air be cold, with a sharp north wind, and if no vapors be escaping, the operator should stand on his guard, for in such circumstances a serious explosion may ensue.

As soon as both the boilers are in full work the air is expelled, the fumes cease, and every hazard is at an end. He should bend his whole attention to the cutting off all communication with the atmosphere, securing simply the mobility of the valves, and a steady vigor of distillation. The conclusion of the process is ascertained by introducing his sounding-rod into the pot, through a small orifice made for its passage in the wall. A new charge must then be given.

By the above process, well conducted, sulphurs are brought to the most perfect state of purity that the arts can require; while not above four parts in the hundred of the sulphur itself are consumed; the crude, incombustible residuum varying from five to eight parts, according to the nature of the raw material. But in the sublimation of sulphur, the frequent combustions inseparable from this operation carry the loss of weight in flowers to about twenty per cent. See SULPHUR, for a figure of the subliming apparatus.

The process by fusion, performed at some of the public works in this country, does not afford a return at all comparable with that of the above French process, though a much better article is operated upon in England. After two meltings of rough sulphur (as imported from Sicily or Italy), eighty-four per cent. is the maximum amount obtained, the average being probably under eighty; while the product is certainly inferior in quality to that by distillation.

3. *On the charcoal.*—Tender and light woods, capable of affording a friable and porous charcoal, which burns rapidly away, leaving the smallest residuum of ashes, and containing therefore the largest proportion of carbon, ought to be preferred for charring in gunpowder works.

After many trials made long ago, black dogwood came to be preferred to every plant for this purpose; but modern experiments have proved that many other woods afford an equally suitable charcoal. The woods of black alder, poplar, lime-tree, horse-chestnut, and chestnut-tree, were carbonized in exactly similar circumstances, and a similar gunpowder was made with each, which was proved by the same proof-mortar. The following results were obtained:—

	Toises.	Feet.
Poplar—mean range - - -	113	2
Black alder - - - - - -	110	4
Lime - - - - - -	110	3
Horse-chestnut - - - - -	110	3
Chestnut-tree - - - - -	109	

By subsequent experiments, confirmatory of the above, it has been further found that the willow presents the same advantages as the poplar, and that several shrubs, such as the hazel-nut, the spindle-treee, the dogberry, the elder-tree, the common sallow, and some others, may be as advantageously employed. But whichever wood be used, we should always cut it when full of sap, and never after it is dead; we should choose branches not more than five or six years old, and strip them carefully, because the old branches and the bark contain a larger proportion of earthy constituents. The branches ought not to exceed three quarters of an inch in thickness, and the larger ones should be divided lengthwise into four, so that their pith may be readily burned away.

Wood is commonly carbonized in this country into gunpowder-charcoal in cast-iron cylinders, with their axes laid horizontally, and built in brick-work, so that the flame of a furnace may circulate round them. One end of the cylinder is furnished with a door, for the introduction of the wood and the removal of the charcoal; the other end terminates in a pipe, connected with a worm-tub for condensing the pyroligneous acid, and giving vent to the carbureted hydrogen gases that are disengaged. Towards the end of the operation, the connexion of the cylinder with the pyroligneous acid cistern ought to be cut off, and a very free egress opened for the volatile matter, otherwise the charcoal is apt to get coated with a fuliginous varnish, and to be even penetrated with condensable matter, which materially injure its qualities.

In France, the wood is carbonized for the gunpowder works either in oblong vaulted ovens, or in pits, lined with brick-work or cylinders of strong sheet-iron. In either case, the heat is derived from the imperfect combustion of the wood itself to be charred. In general, the product in charcoal by the latter method is from 16 to 17 parts, by weight, from 100 of wood. The pit-process is supposed to afford a more productive return, and a better article; since the body of wood is much greater, and the fuliginous vapors are allowed a freer escape. The surface of a good charcoal should be smooth, but not glistening. See CHARCOAL.

The charcoal is considered by the scientific manufacturers to be the ingredient most influential, by its fluctuating qualities, upon the composition of gunpowder; and, therefore, it ought always to be prepared under the vigilant and skilful eye of the director of the powder establishment. If it has been kept for some time, or quenched at first with water, it is unsuitable for the present purpose. Charcoal extinguished in a close vessel by exclusion of air, and afterwards exposed to the atmosphere, absorbs only from three to four per cent. of moisture, while red-hot charcoal quenched with water may lose by drying twenty-nine per cent. When the latter sort of charcoal is used for gunpowder, a deduction of weight must be made for the water present. But charcoal which has remained long impregnated with moisture, constitutes a most detrimental ingredient of gunpowder.

4. *On mixing the Constituents and forming the Powder.*

The three ingredients thus prepared are ready for manufacturing into gunpowder. They are, 1. Separately ground to a fine powder, which is passed through sorted silk sieves or bolting machines. 2. They are mixed together in the proper proportions, which we shall afterwards discuss. 3. The composition is then sent to the gunpowder mill, which consists of two edge-stones of a calcareous kind, turning by means of a horizontal shaft, on a bed-stone of the same nature; incapable of affording sparks by collision with steel, as sand-stones would do. On this bed-stone the composition is spread, and moistened with as small a quantity of water as will, in conjunction with the weight of the revolving stones, bring it into a proper body of cake, but by no means into a pasty state. The line of contact of the rolling edge-stone is constantly preceded by a hard copper scraper, which goes round with the wheel, regularly collecting the caking mass, and bringing it into the track of the stone. From 50 to 60 pounds of cake are usually worked at one operation, under each millstone. When the mass has been thoroughly kneaded and incorporated, it is sent to the corning-house, where a separate mill is employed to form the cake into grains or corns. Here it is first pressed into a hard firm mass, then broken into small lumps; after which the corning process is performed, by placing these lumps in sieves, on each of which is laid a disc or flat cake of lignum vitæ. The sieves are made of parchment skins, or of copper, perforated with a multitude of round holes. Several such sieves are fixed in a frame, which, by proper machinery, has such a motion given to it as to make the lignum vitæ runner in each sieve move about with considerable velocity, so as to break down the lumps of the cake, and force its substance through the holes, in grains of certain sizes. These granular particles are afterwards separated from the finer dust by proper sieves and *reels*.

The corned powder must now be hardened, and its rougher angles removed, by causing it to revolve in a close reel or cask turning rapidly round its axis. This vessel resembles somewhat a barrel-churn, and is frequently furnished inside with square bars parallel to its axis, to aid the polish by attrition.

The gunpowder is finally dried, which is now done generally with a steam heat, or in some places by transmitting a current of air, previously heated in another chamber, over canvass shelves, covered with the damp grains.

5. *On the proportion of the Constituents.*

A very extensive suite of experiments, to determine the proportions of the constituents for producing the best gunpowder, was made at the Essonne works, by a commission of French chemists and artillerists, in 1794.

Powders in the five following proportions were prepared :—

	Nitre.	Charcoal.	Sulphur.	
1	76	14	10	Gunpowder of Bâle.
2	76	12	12	Gunpowder works of Grenelle.
3	76	15	9	M. Guyton de Morveau.
4	77·32	13·44	9·24	Idem.
5	77·5	15	7·5	M. Riffault.

The result of more than two hundred discharges with the proof-mortar showed that the first and third gunpowders were the strongest; and the commissioners in consequence recommended the adoption of the third proportions. But a few years thereafter it was thought proper to substitute the first set of proportions, which had been found equal in force to the other, as they would have a better keeping quality, from containing a little more sulphur and less charcoal. More recently still, so strongly impressed have the French government been with the high value of durability in gunpowders, that they have returned to their ancient dosage of 75 nitre, 12½ charcoal, and 12½ sulphur. In this mixture, the proportion of the substance powerfully absorbent of moisture, viz., the charcoal, is still further reduced, and replaced by the sulphur, or the conservative ingredient.

If we inquire how the maximum gaseous volume is to be produced from the chemical reaction of the elements of nitre on charcoal and sulphur, we shall find it to be by the generation of carbonic oxyde and sulphurous acid, with the disengagement of nitrogen. This will lead us to the following proportions of these constituents.

	Hydrogen = 1.	Per cent
1 prime equivalent of nitre - - -	102	75·00
1 sulphur - -	16	11·77
3 charcoal - -	18	13·23
	136	100·00

The nitre contains five primes of oxygen, of which three, combining with the three of charcoal, will furnish three of carbonic oxyde gas, while the remaining two will convert the one prime of sulphur into sulphurous acid gas. The single prime of nitrogen is, therefore, in this view, disengaged alone.

The gaseous volume, on this supposition, evolved from 136 grains of gunpowder, equivalent in bulk to 75½ grains of water, or to three tenths of a cubic inch, will be, at the atmospheric temperature, as follows:—

	Grains.		Cubic Inches.
Carbonic oxyde - - - - -	42	=	141·6
Sulphurous acid - - - - -	32	=	47·2
Nitrogen - - - - - -	14	=	47·4
			236·2

being an expansion of one volume into 787·3. But as the temperature of the gases at the instant of their combustive formation must be incandescent, this volume may be safely estimated at three times the above amount, or considerably upwards of two thousand times the bulk of the explosive solid.

But this theoretical account of the gases developed does not well accord with the experimental products usually assigned, though these are probably not altogether exact. Much carbonic acid is said to be disengaged, a large quantity of nitrogen, a little oxyde of carbon, *steam of water*, with *carbureted and sulphureted hydrogen.* From experiments to be presently detailed, I am convinced that the amount of these latter products printed in italics must be very inconsiderable indeed, and unworthy of ranking in the calculation; for, in fact, fresh gunpowder does not contain above one per cent. of water, and can therefore yield little hydrogenated matter. Nor is the hydrogen in the carbon of any consequence.

It is obvious that the more sulphur is present, the more of the dense sulphurous acid will be generated, and the less forcibly explosive will be the gunpowder. This is sufficiently confirmed by the trials at Essonne, where the gunpowder that contained 12 of sulphur and 12 of charcoal in 100 parts, did not throw the proof-shell so far as that which contained only 9 of sulphur and 15 of charcoal. The conservative property is, however, so capital, especially for the supply of our remote colonies and for humid climates, that it justifies a slight sacrifice of strength, which at any rate may be compensated by a small addition of charge.

Table of Composition of different Gunpowders.

	Nitre.	Charcoal.	Sulphur.
Royal Mills at Waltham Abbey - - -	75	15	10
France, national establishment - -	75	12·5	12·5
French, for sportsmen - - - - -	78	12	10
French, for mining - - - - - -	65	15	20
United States of America - - - -	75	12·5	12·5
Prussia - - - - - - - - -	75	13·5	11·5
Russia - - - - - - - - -	73·78	13·59	12·63
Austria (*musquet*) - - - - - -	72	17	16
Spain - - - - - - - - -	76·47	10·78	12·75
Sweden - - - - - - - - -	76	15	9
Switzerland (a round powder) - - -	76	14	10
Chinese - - - - - - - - -	75	14·4	9·9
Theoretical proportions (as above) - -	75	13·23	11.77

6. *On the Chemical Examination of Gunpowders.*

I have treated five different samples: 1. The government powder made at Waltham Abbey; 2. Glass gunpowder made by John Hall, Dartford; 3. The treble strong gunpowder of Charles Lawrence and Son; 4. The Dartford gunpowder of Pigou and Wilks; 5. Superfine treble strong sporting gunpowder of Curtis and Harvey. The first is coarse-grained, the others are all of considerable fineness. The specific gravity of each was taken in oil of turpentine: that of the first and last three was exactly the same, being 1·80; that of the second was 1·793, all being reduced to water as unity.

The above density for specimen first, may be calculated thus:—

75 parts of nitre, specific gravity = 2·000
15 parts of charcoal, specific gr. = 1·154
10 parts of sulphur, specific gr. = 2·000

The volume of these constituents is 55·5 (the volume of their weight of water being 100); by which if their weight 100 be divided, the quotient is 1·80.

The specific gravity of the first and second of the above powders, including the interstices of their grains, after being well shaken down in a vial, is 1·02. This is a curious result, as the size of the grains is extremely different. That of Pigou and Wilks, similarly tried, is only 0·99; that of the Battle powder is 1·03; and that of Curtis and Harvey is nearly 1·05. Gunpowders thus appear to have nearly the same weight as water, under an equal bulk; so that an imperial gallon will hold from 10 pounds to 10 pounds and a half, as above shown.

The quantities of water which 100 grains of each part with on a steam bath, and absorb when placed for 24 hours under a moistened receiver standing in water, are as follows:—

100 grains of Waltham Abbey, lose	1·1	by steam heat, gain	0·8	over water.
of Hall - -	0·5	- - -	2·2	
Lawrence - -	1·0	- - -	1·1	
Pigou and Wilks -	0·6	- - -	2·2	
Curtis and Harvey -	0·9	- - -	1·7	

Thus we perceive that the large-grained government powder resists the hygrometric influence better than the others; among which, however, Lawrence's ranks nearly as high. These two are therefore relatively the best keeping gunpowders of the series.

The process most commonly practised in the analysis of gunpowder, seems to be tolerably exact. The nitre is first separated by hot distilled water, evaporated and weighed. A minute loss of salt may be counted on, from its known volatility with boiling water. I have evaporated always on a steam bath. It is probable that a small portion of the lighter and looser constituent of gunpowder, the carbon, flies off in the operations of corning and dusting. Hence, analysis may show a small deficit of charcoal below the synthetic proportions originally mixed. The residuum of charcoal and sulphur left on the double filter-paper, being well dried by the heat of ordinary steam, was estimated, as usual, by the difference of weight of the inner and outer papers. This residuum was cleared off into a platina capsule with a tooth-brush, and digested in a dilute solution of potash at a boiling temperature. Three parts of potash are fully sufficient to dissolve out one of sulphur. When the above solution is thrown on a filter, and washed first with a very dilute solution of potash boiling hot, then with boiling water, and afterwards dried, the carbon will remain ; the weight of which deducted from that of the mixed powder, will show the amount of sulphur.

I have tried many other modes of estimating the sulphur in gunpowder more directly, but with little satisfaction in the results. When a platina capsule, containing gunpowder spread on its bottom, is floated in oil, heated to 400° Fahrenheit, a brisk exhalation of sulphur fumes rises, but, at the end of several hours, the loss does not amount to more than one half of the sulphur present.

The mixed residuum of charcoal and sulphur digested in hot oil of turpentine gives up the sulphur readily; but to separate again the last portions of the oil from the charcoal or sulphur, requires the aid of alcohol.

When gunpowder is digested with chlorate of potash and dilute muriatic acid, at a moderate heat in a retort, the sulphur is acidified; but this process is disagreeable and slow, and consumes much chlorate. The resulting sulphuric acid being tested by nitrate of baryta, indicates of course the quantity of sulphur in the gunpowder. A curious fact occurred to me in this experiment. After the sulphur and charcoal of the gunpowder had been quite acidified, I poured some solution of the baryta salt into the mixture, but no cloud of sulphate ensued. On evaporating to dryness, however, and redissolving, the nitrate of baryta became effective, and enabled me to estimate the sulphuric acid generated; which was of course 10 for every 4 of the sulphur.

The acidification of the sulphur by nitric or nitro-muriatic acid is likewise a slow and unpleasant operation.

By digesting gunpowder with potash water, so as to convert its sulphur into a sulphuret, mixing this with nitre in great excess, drying and igniting, I had hoped to convert the sulphur readily into sulphuric acid. But on treating the fused mass with dilute nitric acid, more or less sulphurous acid was exhaled. This occurred even though chlorate of potash had been mixed with the nitre to aid the oxygenation.

The following are the results of my analyses, conducted by the first described method :

100 grains afford, of	Nitre.	Charcoal.	Sulphur.	Water.
Waltham Abbey - -	74·5	14·4	10·0	1·1
Hall, Dartford - - -	76·2	14·0	9·0	0·5 loss 0·3
Pigou and Wilks - -	77·4	13·5	8·5	0·6
Curtis and Harvey -	76·7	12·5	9·0	1·1 loss 0·7
Battle gunpowder -	77·0	13·5	8·0	0·8 loss 0·7

It is probable, for reasons already assigned, that the proportions mixed by the manufacturers may differ slightly from the above.

The English sporting gunpowders have long been an object of desire and emulation in France. Their great superiority for fowling pieces over the product of the French national manufactories, is indisputable. Unwilling to ascribe this superiority to any genuine cause, M. Vergnaud, captain of French artillery, in a little work on fulminating powders lately published, asserts positively, that the English manufacturers of 'poudre de chasse' are guilty of the 'charlatanisme' of mixing fulminating mercury with it. To determine what truth was in this allegation, with regard at least to the above five celebrated gunpowders, I made the following experiments.

One grain of fulminating mercury, in crystalline particles, was mixed in water with 200 grains of the Waltham Abbey gunpowder, and the mixture was digested over a lamp with a very little muriatic acid. The filtered liquid gave manifest indications of the corrosive sublimate, into which fulminating mercury is instantly convertible by muriatic acid; for copper was quicksilvered by it; potash caused a white cloud in it that became yellow, and sulphureted hydrogen gas separated a dirty yellow white precipitate of bisulphuret of mercury. When the Waltham Abbey powder was treated alone with dilute muriatic acid, no effect whatever was produced upon the filtered liquid by the sulphureted hydrogen gas.

200 grains of each of the above sporting gunpowders were treated precisely in the same way, but no trace of mercury was obtained by the severest tests. Since by this process there is no doubt but one 10,000th part of fulminating mercury could be detected, we may conclude that Captain Vergnaud's charge is groundless. The superiority of our sporting gunpowders is due to the same cause as the superiority of our cotton fabrics—the care of our manufacturers in selecting the best materials, and their skill in combining them.

I shall subjoin here some miscellaneous observations upon gunpowder.

In Bengal, mixing is performed by shutting up the ingredients in barrels, which are turned either by hand or machinery; each containing 50 lbs. weight, or more, of small brass balls. They have ledges on the inside, which occasion the balls and composition to tumble about and mingle together, so that the intermixture of the ingredients, after the process has been gone through, cannot fail to be complete. The operation is continued two or three hours; and I think it would be an improvement in Her Majesty's system of manufacture if this method of mixing were adopted.

In England two or three pints of water are used for a 42 lb. charge: but the quantity is variable; both the temperature and the humidity of the atmosphere influence it.

Bramah's hydrostatic press, or a very strong wooden press working with a powerful screw, lever, and windlass, constitutes the description of mechanism by which density is imparted to gunpowder. The incorporated or mill-cake powder is laid on the bed or follower of the press, and separated, at equal distances, by sheets of copper, so that when the operation is over, it comes out in large thin solid cakes, or strata, distinguished by the term press-cake. The mill-cake powder at Waltham Abbey, is submitted to a mean theoretic pressure of 70 to 75 tons per superficial foot.

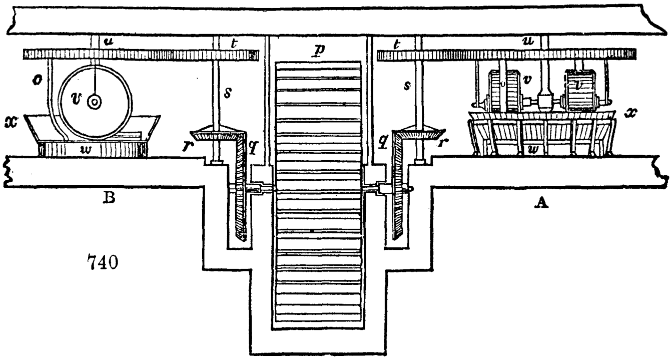
Gunpowder should be thoroughly dried, but not by too high a degree of heat; that of 140° or 150° of Fahrenheit's thermometer is sufficient. It appears to be of no consequence whether it be dried by solar heat, by radiation from red-hot iron, as in the gloom stove, or by a temperature raised by means of steam. Her Majesty's gunpowder is dried by the last two methods. The grain should not be suddenly exposed to the highest degree of heat, but gradually.

The method of trial best adapted to show the real inherent strength and goodness of gunpowder, appears to be an eight or ten inch iron or brass mortar, with a truly spherical solid shot, having not more than one tenth of an inch windage, and fired with a low charge. The eight-inch mortar, fired with two ounces of powder, is one of the established methods of proof at Her Majesty's works. Gunpowders that range equally in this mode of trial, may be depended on as being equally strong.

Another proof is by four drachms of powder laid in a small neat heap, on a clean, polished copper plate; which heap is fired at the apex, by a red hot iron. The explosion should be sharp and quick; not tardy, nor lingering; it should produce a sudden concussion in the air; and the force and power of that concussion ought to be judged of by comparison with that produced by powder of known good quality. No sparks should fly off, nor should beads, or globules of alkaline residuum, be left on the copper. If the copper be left clean, i. e. without gross foulness, and no lights, i. e. sparks, be seen, the ingredients may be considered to have been carefully prepared, and the powder to have been well manipulated, particularly if pressed and glazed; but if the contrary be the result, there has been a want of skill or of carefulness manifested in the manufacture.

"Gunpowder," says Captain Bishop, "explodes exactly at the 600° of heat by Fahrenheit's thermometer; when gunpowder is exposed to 500° it alters its nature altogether; not only the whole of the moisture is driven off, but the saltpetre and sulphur are actually reduced to fusion, both of which liquefy under the above degree. The powder, on cooling, is found to have changed its color from a gray to a deep black; the grain has become extremely indurated, and by exposure even to very moist air, it then suffers no alteration by imbibing moisture."

The mill for grinding the gunpowder cake may be understood from the following representation (*fig.* 740); *p*, is the water wheel, which may drive several pairs of stones; *q*, *q*, two vertical bevel wheels, fixed upon the axis of the great wheel· *r*, *r*, two



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horizontal bevel wheels working in *q*, *q*, and turning the shafts *s*, *s*; *t*, *t*, two horizontal spur wheels fixed to the upper part of the vertical shafts, and driving the large wheels *u*, *u*. To the shafts of these latter wheels are fixed the runners *v*, *v*, which traverse upon the bed stone *w*, *w*; *x*, *x*, are the curbs surrounding the bed stone to prevent the powder from falling off; *o* is the scraper. Mill A represents a view, and mill B a section of the bed stone and curb.

Gunpowder, *Analysis of.* M. Bolley dissolves out the sulphur from charcoal in gunpowder (previously freed from its nitre by water) by digesting it, at a boiling heat for 2 hours, with the solution of 20 times its weight of sulphite of soda, which is thereby converted into hyposulphite. To the mixture water must be added, as it is wasted by the boiling. If the residum be heated on platinum foil, it will exhale sulphur, if this had not been all removed by the sulphurous salt.

GUTTA PERCHA (Native). "Although the trees yielding this substance abound in the forests of the Indian Archipelago, the first notice taken of it appears to have been by Dr. W. Montgomerie, in a letter to the Bengal Medical Board, in the beginning of 1843, wherein he recommends the substance as likely to prove useful for some surgical purposes, and supposes it to belong to the fig tribe. In April, 1843, the substance was taken to Europe by Dr. D'Almeida, who presented it to the Royal Society of Arts of London, but it did not at first attract much attention, as the Society simply acknowledged the receipt of the gift; whereas shortly after they thought proper to award a gold medal to Dr. W. Montgomerie for a similar service. Now, as the discovery of both of these gentlemen rested pretty much upon the same foundation, the accidental falling in with it in the hands of some Malays, who had found out its greatest peculiarity, and availed themselves thereof, manufactured it into whips, which were brought into town for sale, there does not appear any plausible reason for the passing over the first, and rewarding the second. Both gentlemen are highly to be commended for endeavouring to introduce to public notice a substance which has proved so useful and interesting. The gutta percha having of late attracted much attention, and as yet but little being known or published about it, I would now propose to supply, to the best of my ability, this desideratum, and give a description of the tree, its product and uses, so far as it has been made available for domestic and other purposes in the place of its origin.

"The gutta percha, tree, or gutta tuban, as it ought more properly to be called, the percha producing a spurious article, belongs to the natural family *Sapoteæ*, but differs so much from all described genera, having alliance with both *Achras* and *Bassia*, but differing in some essentials from both, that I am disposed to think it is entitled to rank as a new genus. I shall, therefore, endeavour to give its general character, leaving the honour of naming it to some more competent botanist, especially as I have not quite satisfied myself regarding the stamens, from want of specimens for observations.

"The tree is of a large size, from 60 to 70 feet in height, and from 2 to 3 feet in diameter. Its general appearance resembles the genus *Durio*, or well known *Doorian*, so much so as to strike the most superficial observer. The under surface of the leaf, however, is of a more reddish and decided brown than in the Durio, and the shape is somewhat different.

"It is quite extraordinary how difficult it is to obtain specimens of either the flower or the fruit of this tree, and this is probably the reason of its not having been earlier recognised and described by some of the many botanists who have visited these parts.

"Only a short time ago the tuban tree was tolerably abundant on the island of Singapore; but already all the large timber has been felled, and few, if any, other than small plants are now to be found. The range of its growth, however, appears to be considerable, it being found all up the Malayan Peninsula, as far as Penang, where I have ascertained it to be abundant; although, as yet, the inhabitants do not seem to be aware of the fact, several of the mercantile houses there having sent down orders to Singapore for supplies of the article, when they have the means of supply close at hand. The tree is also found in Borneo, and, I have little doubt, is to be found in most of the islands adjacent.

"The localities it particularly likes are the alluvial tracts along the foot of hills, where it flourishes luxuriantly, forming, in many spots, the principal portion of the jungle. But, notwithstanding the indigenous character of the tree, its apparent abundance and widespread diffusion, the gutta will soon become a very scarce article, if some more provident means be not adopted in its collection than those at present in use by the Malays and Chinese.

"The mode in which the natives obtain the gutta is by cutting down the trees of full growth, and ringing the bark at distances of about 12 to 18 inches apart, and placing a cocoa-nut shell, spathe of a palm or such like receptacle, under the fallen trunk, to receive the milky sap that immediately exudes upon every fresh incision. This sap is collected in bamboos, taken to their houses, and boiled, in order to drive off the watery particles and inspissate it to the consistence it finally assumes. Although the process of boiling appears necessary when the gutta is collected in large quantities, if a tree be freshly wounded, a small quantity allowed to exude, and it be collected and moulded in the hand, it will consolidate perfectly in a few minutes, and have all the appearance of the prepared article.

"When it is quite pure the colour is of a grayish white; but, as brought to market, it is more ordinarily found of a reddish hue, arising from chips of bark that fall into the sap in the act of making the incisions, and which yield their colour to it. Besides these accidental chips there is a great deal of intentional adulteration by sawdust and other materials. Some specimens I have lately seen brought to market could not have contained much less than ¼ lb. of impurities; and even in the purest specimens I could obtain for surgical purposes, one pound of the substance yielded on being cleansed one ounce of impurities; fortunately, it is neither difficult to detect or clean the gutta of foreign matter, it being only necessary to boil it in water until well softened, roll out the substance into thin sheets, and then pick out all impurities, which is easily done as the gutta does not adhere to anything, and all foreign matter is merely entangled in its fibres, not incorporated in its substance. The quantity of gutta obtained from each tree varies from 5 to 20 catties, so that, taking the average at 10 catties, which is a tolerably liberal one, it will require the destruction of ten trees to produce one picul. Now, the quantity exported from Singapore to Great Britain and the continent, from 1st January 1845 to the present date, amounted to 6,918 piculs, to obtain which 69,180 trees must have been sacrificed. How much better would it, therefore, be to adopt the method of tapping the tree, practised by the Burmese in obtaining the caoutchouc from the *Ficus elastica* (viz. to make oblique incisions in the bark, placing bamboos to receive the sap which runs out freely), than to kill the goose in the manner they are at present doing! True, they would not at first get so much from a single tree, but the ultimate gain would be incalculable, particularly as the tree seems to be one of slow growth; by no means so rapid as the *Ficus elastica.* I should not be surprised, if the demand increases, and the present method of extermination be persisted in, to find a sudden cessation of the supply.

"*Properties of the Gutta.*—This substance when fresh and pure is, as already mentioned, of a dirty white colour, and of a greasy feel, with a peculiar leathery smell. It is not affected by boiling alcohol, but dissolves readily in boiling spirits of turpentine, also in naphtha and coal-tar. A good cement for luting bottles and other purposes is formed by boiling together equal parts of gutta and coal-tar and resin. I am indebted for this hint to Mr. Little, surgeon, and the above were his proportions. I have, however, found it necessary to put two parts of the gutta, that is, one-half instead of one-third, to enable the cement to stand the heat of this climate. When required for use, it can always be made plastic by putting the pot containing it over the fire for a few minutes. The gutta itself is highly inflammable; a strip cut off takes light, and burns with a bright flame, emitting sparks, and dropping a black residuum in the manner of sealing wax, which in its combustion it very much resembles. But the great peculiarity of this substance, and that which makes it so eminently useful for many purposes, is the effect of boiling water upon it. When immersed for a few minutes in water above 150° Fahr., it becomes soft and plastic, so as to be capable of being moulded to any required shape or form, which it retains upon cooling. If a strip of it be cut off and plunged into boiling water, it contracts in size both in length and breadth. This is a very anomalous and remarkable phenomenon, apparently opposed to all the laws of heat.

"It is this plasticity when plunged into boiling water that has allowed of its being applied to so many useful purposes, and which first induced some Malays to fabricate it into whips, which were brought into town, and led to its further notice. The natives have subsequently extended their manufactures to buckets, basins, and jugs, shoes, traces, vessels for cooling wines, and several other domestic uses; but the number of patents lately taken out for the manufacture of the article in England, proves how much attention it has already attracted, and how extensively useful it is likely to become. Of all the purposes, however, to which it may be adapted, none is so valuable as its applicability to the practice of surgery. Here it becomes one of the most useful auxiliaries to that branch of the healing art which of all is the least conjectural. Its easy plasticity and power of retaining any shape given to it when cool, at once pointed it out as suitable for the manufacture of bougies; and accordingly my predecessor, Dr. W. Montgomerie, availed himself of this, made several of the above instruments, and recommended the use of it to the Bengal Medical Board. But, like many other good hints, for want of sufficient inquiry, I fear it was disregarded. The practice, however, has been continued by me, and I find many advantages in the use of this substance. It also answers very well for the tubes of syringes, which are always getting out of order in this country, when made of caoutchouc. But my late experiments have given it a much higher value, and proved it the best and easiest application ever yet discovered in the management of fractures, combining ease and comfort to the patient, and very much lessening the trouble of the surgeon. When I think of the farrago of bandages and splints got rid of, the lightness and simplicity of the application, the gutta would be no trifling boon to mankind, were it to be used solely for this and no other purpose. The injuries coming under my observation, wherein I have tested its utility, have, as yet, only been two compound fractures of the leg, and one of the jaw; but so admirably has it not only answered, but exceeded my expectations, that I should think myself culpable in not giving the facts early publicity. Its utility in fracture of the lower jaw must at once strike any surgeon. So well does it mould itself to every sinuosity, that it is more like giving the patient a new bone than a mere support. A man lately brought into hospital, who had his lower jaw broken by the kick of a horse, and which was so severe as to cause hæmorrhage from the ears, smashing the bone into several fragments, was able to eat and speak three days after the accident, and felt so well with his gutta splint that he insisted on leaving the hospital within ten days. My mode of applying this substance to fractures of the leg is as follows:—

"The gutta having been previously rolled out into sheets of convenient size, and about one-fourth of an inch in thickness, is thus kept ready for use. When required, a piece of the necessary length and breadth is plunged into a tub of boiling water. The limb of the patient is then gently raised by assistance, making extension in the usual manner. The surgeon, having ascertained that the broken bone is in its place, takes the sheet of gutta out of the hot water, and allows it to cool for a couple of minutes. It is still soft and pliable as wash leather. Place it whilst in this state under the limb, and gently lower the latter down on it. The gutta is then to be brought round and moulded carefully to the whole of the back and sides of the leg, bringing the edges close together, but not uniting them. If there be any superfluous substance, it can be cut off with scissors, leaving an open slit down the front of the leg. You have now the leg in a comfortable, soft, and smooth case, which in ten minutes will be stiff enough to retain any shape the surgeon may have given it, and which will also retain the bone *in situ*. Place the leg so done up on a double incline plane, and secure it thereto by passing three of the common loop bandages around the whole; that is, one at the top, one in the middle, and one at the lower end. Let the foot be supported by a foot-board, and a case of gutta put over the dorsum of the foot, to bear off the pressure of the small bands generally used to secure it to the board. Having done this, the surgeon need not cause the patient another twinge of pain until he thinks he can use the leg, or he deems the bone sufficiently united to bear the weight of his patient. If it be a compound fracture, it will be only necessary to untie the loop bandages, separate the edges of the gutta splint to the required distance, wash and cleanse the limb without shifting anything except the dressings, and, having done so, shut it up again. The most perfect cleanliness can be maintained, as the gutta is not affected by any amount of ablution; neither is it soiled or rendered offensive by any discharge, all which washes off as easily from the gutta case as from oil-cloth. I have had a patient where the tibia protruded through the integuments fully two inches, walking about in six weeks from the injury, with a leg as straight and well formed as ever it had been. It is quite obvious, therefore, that if it answers so well for compound, it will answer equally, if not better, for simple fractures; and that any broken bone capable of receiving mechanical support can be supported by the gutta better than by any other contrivance; for it combines lightness, and smoothness, and durability, and a capability of adjustment not possessed by any other known substance. All new experiments have to run the gauntlet of opposition; and I do not suppose that these recommendations will prove any exception to the rule; but all I ask of any surgeon is, to try the experiment ere he argues on its propriety, and I feel fully convinced that all other splints and bandages will be consigned to the tomb of the Capulets. There are some other uses for which I have tried this substance, viz., as capsules for transmission of the vaccine virus, which ought to keep well when thus protected, for it is most perfectly and hermetically sealed; but I have not had sufficient experience in this mode of using it to pronounce decidedly on its merits. I am at present trying the effects of it on ulcers, by enclosing the ulcerated limb in a case of gutta, so as to exclude all atmospheric air; and so far, the experiment promises success.

"Since writing the foregoing observations, I have had an official intimation from Penang, of the vaccine virus transmitted in the gutta capsules having been received in good order, and of its having succeeded satisfactorily. I have also opened a capsule containing a vaccine crust that had been kept here for one month, and it also seems to have lost none of its efficacy, as the case inoculated has taken. This will appear the more striking when it is recollected that, to preserve the vaccine virus hitherto in Singapore, even for a few days, has been almost impossible; that this settlement, notwithstanding every exertion on the part of both private and public practitioners, has been without the benefit of this important prophylactic for an interval sometimes of two years; and that, at all times, the obtaining and transmitting this desirable remedy has been a cause of trouble and difficulty to all the medical officers I have ever met with in the Straits."—*Mr. T. Oxley, Surgeon, Prince of Wales Island and Malacca.*

"I observed in the *Mechanics' Magazine* for March, 1847, a notice of several patents taken out for the working of the article by Mr. Charles Hancock, in which an elaborate process is described for cleaning the gutta, as also mention of its having a disagreeable acid smell. The gutta, when pure, is certainly slightly acid, that is, it will cause a very slight effervescence when put into a solution of soda, but is unaffected by liquor potassæ. The smell, although peculiar, is neither strong nor unpleasant, so that the article experimented upon must have been exceedingly impure, and possibly derived a large portion of its acidity from the admixture and fermentation of other vegetable substances. Again; it appears to me that, if the gutta be pure, the very elaborate process described as being necessary for cleaning it, is superfluous. The gutta can be obtained here in a perfectly pure state by simply boiling it in hot water until well softened, and then rolled out into thin sheets, when, as I have before said, all foreign matter can be easily removed. I would recommend that the manufacturers at home should offer a higher price for the article if previously strained through cloth at the time of being collected, when they will receive the gutta in a state that will save them a vast deal more in trouble and expense than the trifling addition necessary to the original prime cost."—*Mr. Oxley.*

In February, 1847, Mr. Charles Hancock obtained a patent for improvements in the manufacture of gutta percha, consisting, in the first place, in the construction of a slicing machine, consisting of a circular iron plate, formed with three radial slots, in which knives are fixed in a similar manner to the irons of an ordinary plane or spoke shave; the shaft which carries the plate is caused to rotate by steam or other power. The lumps of gutta percha drop against the knives, a plate by which they are cut into slices, of a degree of thickness corresponding to the projection given to the knives. These slices are then soaked in a vessel of hot water till they become pliable. Instead of a circular revolving cutter, a vertical cutter or chopper may be used; curved knives may be had recourse to for refractory lumps. The softened slices are next subjected to the action of breakers or rollers with serrated blades, which are mounted transversely over the tank. In front of each breaker there is a pair of fluted feeding rollers; and the pieces of gutta percha are passed to the rollers of the first breaker. There is an inclined endless web mounted upon two rollers, the front one of which is immersed in the water, and the other is situated opposite the space between the feeding rollers of the second breaker. There is a second inclined web placed before the third breaker. There is also a mincing cylinder with radial blades working partly in the water. The feeding-rollers, and the carrying-rollers of the endless webs, are made to revolve in a forward direction, while the breakers, the mincing cylinder, and the agitator, are made to revolve in the opposite direction. The breakers and mincing cylinder should revolve at the rate of from 600 to 800 revolutions per minute, but the feeding rollers and endless webs need not move faster than about one-sixth of that rate. Thus, the substance is reduced to small fragments and washed in the water, the heavy impurities falling to the bottom of the tanks, and the lighter and purer matter floating. The water should be used cold. When the gutta percha has a fetid smell, it is treated with carbonate of soda or chloride of lime. The said apparatus may be used also for purifying caoutchouc and jintawan.

Mr. Hancock now considers the use of sulphur to be altogether objectionable by itself on account of its offensive smell and efflorescing property as a means of vulcanizing caoutchouc. He has found that if a minute portion of sulphur be used along with a sulphuret the best result is obtained; the proper proportions being 6 parts of sulphuret of antimony, or hydrosulphuret of lime, and 1 part of sulphur to 48 parts of gutta percha or caoutchouc. When these materials have been mixed, the compound is put into a boiler and heated under pressure to a temperature of from 260° to 300° F. and is to be left in this state for a period varying from half an hour to two hours, according to the thickness of the materials. He prefers for effecting the union of the sulphurous constituent the following method to the masticating machine. 1st. He subjects the purified gutta percha to the conjoined action of steam and the fumes of orpiment and sulphur mixed in the proportions stated, in a metal chamber, provided with a steam-tight cover secured by screw-bolts. There is also a steam boiler connected therewith, and when the heat in it is raised to about 280° Fahr., a fire is lighted beneath the pot containing the sulphuring materials. But the gutta percha, &c. should be heated with the steam before it is sulphured. In from half an hour to two hours the sulphuring is finished. Or, the gutta percha may be rubbed strongly over with the sulphurous mixture and then heated, either dry or with the aid of steam, or coated in the form of a paste along with gutta percha.

Another of Mr. Hancock's inventions is to expose the gutta percha to the deutoxide of azote, or chloride of zinc, concentrated and boiling hot, and then washed with an alkaline solution or mere water. Gutta percha thus treated by the action of nitrous gas, as it is evolved from nitric acid and copper, iron, or zinc, becomes exceedingly smooth, and of a lustre approaching to metallic; so also does common unsulphured caoutchouc. It is thus also freed from all stickiness; while the sulphured acquires under this treatment the downy softness of velvet. Chloride of zinc and nitrous gas remove the smell of vulcanized caoutchouc in a great measure, especially if it be afterwards washed.

Other new inventions are practised by masticating either gutta percha, caoutchouc, or jintawan, in the proportion of 6 parts with 1 of chloride of zinc; all which compounds may be afterwards sulphured. A further modification consists in producing a spongy gutta percha, caoutchouc, or jintawan, for stuffing sofas, &c. 48 parts of one of these, moistened with oil of turpentine, coal naphtha, bisulphuret of carbon, or other proper solvent, 6 parts of hydrosulphuret of lime, sulphuret of antimony, or other analogous sulphuret, 10 parts of carbonate of ammonia, carbonate of lime, or other substance that is either volatile or capable of yielding a volatile product, and 1 part of sulphur. He mixes these materials together in a masticator, and then subjects them to a high degree of heat, observing the same conditions which are stated in the former description, except only that the heat may be pushed with advantage several degrees higher, say from 260° to 300° Fahr.

Articles are manufactured of ordinary gutta percha, caoutchouc, or jintawan, such as single and double texture waterproof fabrics, boots, galoshes, belts, bandages, trousers' and other straps, capes, life-preservers, tubes, knapsacks, caps, cups, and other vessels of capacity, hammer cloths, cotton spinning rollers, backs of cards for carding wool, pianoforte hammers, paper holders, springs, trusses, &c. By taking the gutta percha, caoutchouc, or jintawan, after it has been sulphured, and brushing it with a solution of resin in boiling oil (linseed?), placing it in a chamber heated to from 75° to 100° Fahr., and afterwards polishing it by the means usually employed by the japanners, it acquires the lustre of japanned wares.

Mr. Hancock has also contrived a machine for cutting gutta percha into strips or ribands, thread, or cord of any required shape. It consists of two grooved rollers of iron or steel, mounted in a suitable framework. The grooves of each roller are semicircular, and the projecting divisions between the grooves are made with knife edges, so as to divide readily any sheet or mass of gutta percha presented to them. The under roller is flanged at both ends, and the upper roller is made to fit inside of these flanges, in order to keep the cutting edges from shifting or being damaged. To cut thin sheets of gutta percha with this machine into strips or ribands, the material is passed through it in a cold state, and only the cutting edges are brought into operation. To make round cord or thread by means of it, either a sheet of gutta percha of a thickness equal to the diameter of the holes formed by the grooves, and at a temperature of 200° Fahr. (produced by supplying it from a feeding-chamber heated to that degree) is passed through the machine, and the threads or cords are received in a tank of cold water, from which they are led away to be wound on reels or drums; or the gutta percha is employed in a plastic state, and passed under a gauge before it enters the machine. If it be desired to produce a cord of a semicircular form in the transverse section, a plane roller is substituted for the lower grooved roller; or should cord of a square, triangular, or hexangular, or any other form be required, the two rollers must be shaped to suit.—*Newton's Journal*, xxxv. 96.

Gutta Percha Letters. Gutta Percha has been patented for making letters for shop signs by Mr. Moore, Barrister.

Gutta Percha Tubes; strength of. A series of interesting experiments have just been concluded at the Birmingham Waterworks, relative to the strength of Gutta Percha Tubing, with a view to its applicability for the conveyance of water. The experiments were made (under the direction of Henry Rofe, Esq., engineer,) upon tube ¾ of an inch diameter, and one eighth of gutta percha. These were attached to the iron main, and subjected for two months to a pressure of 200 feet head of water, without being in the slightest degree deteriorated. In order to ascertain if possible the maximum strength of the tubes, they were connected with the Water Company's hydraulic proving pump, the regular load of which is 250 lbs. on the square inch. At this point the tubes were unaffected, and the pump was worked up to 337 lbs., but to the astonishment of every one the tubes still remained perfect. It was then proposed to work the pump up to 500 lbs., but it was found that the lever of the valve would not bear this weight. The utmost power of the hydraulic pump could not break the tubes.

The gutta percha being somewhat elastic, allowed the tubes to become slightly expanded by the extraordinary pressure which was applied, but on its withdrawal they resumed their former size.

Gutta Percha Tubing. This tubing is such an extraordinary conductor of sound, that its value, not only to deaf persons, but to the public generally, will speedily be appreciated. It has already been fitted up in dwelling houses, in lieu of bells;—as speaking tubes for giving and receiving messages in mines, railway stations, prisons, workhouses, hotels, and all large establishments, it is invaluable.

Gutta Percha—*its Properties, Analysis, Elementary Composition and Applications, by M. Payen.* Without possessing any exact information regarding the extraction of the substance which comes to us from the Eastern Archipelago under the name of *gutta percha*, we know that this substance is contained in the descending sap of the *Isonandra Gutta*, Hooker, belonging to the natural order *Sapotaceæ.* This tree attains a great size, being sometimes as much as a yard in diameter, and 60 or 70 feet in height; its soft and fibrous wood is useless for industrial purposes; its fruit furnishes a fatty oil.

It is said that a tree, when cut down, will yield 18 kilogrammes of gutta percha or solid gum. The juices, dried in thin strata laid one upon another, form irregular masses of greater or less thickness, of a reddish or grayish colour, of which a gradually increasing quantity has been annually imported into Europe and America since 1845.

During many years the natives of the countries where it is produced have employed it almost solely in the formation of handles for axes, which possess when cold a certain degree of flexibility with great toughness. At present, the gutta percha is purified by rasping it in cold water, which removes the greater part of the soluble organic matter and salts, and also facilitates the separation of any portions of wood or earthy matters. The purification is completed by means of warm water in several basins; the gutta percha is afterwards dried, and formed into a pasty mass by heating it to about 230° F. in a vessel with a steam jacket.

The gutta percha thus prepared becomes sufficiently soft to be readily joined, stretched out into sheets or straps of any thickness, drawn into tubes of various diameters, and moulded into any form, whilst, on being slowly cooled, it acquires great tenacity and solidity. It is necessary, however, to remark, that the presence of a small quantity of water is sufficient to prevent the adhesion of its parts.

Properties of common Gutta Percha.—The gutta percha thus purified for manufacturing purposes, is of a reddish-brown colour; it readily becomes electrical by friction and is a bad conductor of both electricity and heat. At the ordinary temperature of our climate, say from 32° to 77°, it possesses about as much tenacity as thick leather, with rather less flexibility; it softens and becomes sensibly doughy towards 120°, although still very tough. Its ductility is such, at a temperature of from 110° to 241°, that it is readily extended into thin sheets, or drawn into threads or tubes; its flexibility and ductility diminish as the temperature becomes lower. It does not possess at any temperature the peculiar elastic extensibility which characterizes caoutchouc. Exposed for an hour to a temperature of 14°, its flexibility is slightly diminished.

In its various forms, gutta percha possesses a peculiar porosity, as may be shown in the following manner:—A drop of its solution in sulphuret of carbon is to be placed on a glass slip; the spontaneous evaporation soon reduces this solution to a whitish plate; if it be then examined with the microscope, the numerous cavities with which it is pierced may be distinctly perceived. These cavities may be rendered still more visible by means of a drop of water; the liquid gradually insinuates itself, the mass appears more opake, and by means of the microscope the cavities are seen to be enlarged.

Similar results are obtained by keeping immersed in water for a considerable time thin transparent laminæ, obtained by the evaporation by heat of a solution of gutta percha.

The preceding observations led me to think, that this substance retaining, in consequence of its porosity, a great many minute particles of air, owed to this circumstance its appearance of possessing a less density than that of water, namely 0·979. In fact, on stretching gutta percha under strong pressure, and immediately cutting the strips thus produced into very small pieces under water, the greater part of the fragments fell to the bottom of the vessel—some immediately, others after absorbing a certain quantity of water. The same result was also obtained by keeping very thin leaves of gutta percha, prepared by different methods, immersed for a month in water deprived of air; their pores becoming gradually filled with the liquid, they became heavier than the water, and then ceased to float. Gutta percha is also heavier in proportion to the length of time it has been exposed to the air, particularly in thin leaves.

The porous structure of gutta percha becomes changed into a fibrous texture when it is drawn out so as to double its length; then retaining but little extensibility, it supports, without breaking, the action of a force equal to double that required for its elongation in the first instance.

Common gutta percha resists cold water, damp, and also the various influences which excite fermentation; but it can be softened, and experience a sort of superficial doughy fusion by the action of the solar rays in summer.

It is not attacked by alkaline solutions, even when caustic and concentrated; ammonia, saline solutions, water containing carbonic acid, the various vegetable and mineral acids, do not act upon it; alcoholic liquors (wines, beer, &c.) do not touch it; even brandy scarcely dissolves a trace of it. Olive-oil does not appear to attack gutta percha when cold; when hot, it dissolves a small portion of it, which is again precipitated on cooling.

Sulphuric acid with one equiv. of water colours it brown, and disintegrates it with a sensible evolution of sulphurous acid.

Muriatic acid, in its saturated solution in water at a temperature of 68° F., attacks gutta percha slowly, and gives it a more or less deep brown colour, at length rendering it brittle.

Monohydrated nitric acid attacks it rapidly, with effervescence and an abundant evolution of fumes of hyponitrous acid; the substance is decomposed, and coloured of a brownish-orange red; it becomes doughy, and afterwards solidifies by degrees and remains friable.

In the cold, and even by heat, only a part of the gutta percha (0·15 to 0·22) is dissolved by anhydrous alcohol or ether. Benzine and spirits of turpentine dissolve it partially when cold, but nearly completely by heat. Sulphuret of carbon and chloroform dissolve gutta percha when cold; the solutions may be filtered beneath a bell-glass to prevent evaporation; the filter retains the foreign matters of a reddish-brown colour, whilst the solution passes perfectly clear and almost colourless. The filtered liquid, exposed to the air in a saucer, allows the solvent to escape, and deposits the white gutta percha in a plate of greater or less thickness, which shrinks gradually in proportion to the evaporation of the liquid.

Except the colour, which has disappeared, the gutta percha offers then the characters and properties mentioned above as belonging to the commercial substance. Submitted to a gradually-raised temperature, it softens and melts, and may be made to boil without acquiring a sensible colour; the transparent fluid gives abundant vapours which are condensable into a nearly colourless oily liquid. The portions last distilled have a brownish-orange colour, and a thin layer of carbonaceous deposit remains adherent to the sides of the vessel.

Analysis.—We have said above that alcohol and ether can dissolve only a portion of gutta percha; this is because that substance consists, in fact, of three proximate principles, the separation of which has required very delicate observation, although they are very clearly distinguished by several of their properties.*

When gutta percha in thin leaves is brought into contact, in a close vessel, with 15 to 20 vols. of cold anhydrous alcohol, and the temperature raised slowly by means of the water-bath to the point of ebullition (172° F.), and kept at this point during several hours, the liquid, if filtered whilst boiling and left in a closed flask, will, at the end of from 12 to 36 hours, begin to deposit on the sides of the vessel and on the surface of the solution white opaline granules, distant from one another, but some of them in groups; their size will gradually increase for some days. These granules, carefully examined under the microscope, will be found to have the form of spherules truncated by the sides of the vessel. Their surface is either smooth or bristling, with very small transparent, elongated, lamellar crystals. Some superficial fissures appear to indicate that these spherules are formed of a sort of transparent yellow kernel covered with a white pellicle.

Such is really their singular crystalline structure, of which perhaps no other example is known. In fact, cold anhydrous alcohol dissolves the whole of the yellow, subjacent spheroidal substance, while the superficial pellicle, in the interior of which the alcohol has substituted itself for the solid globule, appear whiter and less transparent.

The alcoholic solution which has been for some days depositing this complex spheroidal crystallization, can again take up by heat a portion of the two proximate principles remaining in the substance, allowing a fresh quantity to crystallize on cooling. The extraction is completed by returning the boiling alcohol several times upon the gutta percha until it no longer dissolves anything.

The solid substance which has resisted the action of the solvent, possesses, with some modifications, the principal properties of crude gutta percha; we shall here call it *pur-gutta* or *gutta.* As to the two other organic principles, one is a *yellow resin,* which is much more soluble in cold alcohol than the other, the *white crystalline resin.*

By taking advantage of these different degrees of solubility, we are enabled, with time and patience, to effect the complete purification of these three principles. The separation may also be effected by treating finely-divided gutta percha with cold ether, which dissolves the mixture of the two resins more abundantly than alcohol; they are afterwards separated from one another by the same treatment already described for alcohol

The tendency of the white resin to form itself into groups of radiated lamellæ is manifested in a rather remarkable circumstance, which it is easy to reproduce. Narrow ribbons cut from a thin leaf of ordinary gutta percha are to be placed in a tube, and immersed in anhydrous alcohol. The tube is then closed, and left for twenty or thirty days, when a few whitish points appear here and there on the ribbons, and afterwards on the sides of the tube. These points, which become gradually larger, are formed of crystalline tufts of the white resin. Thus this proximate principle is separated directly, and in the cold, even when the atmospheric temperature is gradually rising, for instance during the spring or early summer.

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* The author appears to be unacquainted with the researches of M. Arppe on this subject. See Chem. Gaz. vol. ix. p. 471.

The crystalline white resin, when completely purified by washings with alcohol, and then redissolved in anhydrous alcohol, is deposited by slow spontaneous evaporation in the air, in radiated lamellar crystals, forming sometimes symmetrical tufts arranged in stars, and then presenting the appearance of a sort of efflorescence.

Distinctive Characters and Properties of the Three Proximate Principles which constitute common Gutta Percha.—The most abundant of these three principles, forming at least from 75 to 82 per cent. of the whole mass, is the pure gutta, which presents the principal properties of the commercial substance; it is white, transparent at a temperature of 212° F., when all its parts are melted together; opake or semi-transparent when cold, from its then acquiring a structure which causes the interposition of air, or of a liquid possessing a different refraction from its own. This structure appears still more distinct than in the natural substance containing all three principles.

In thin sheets, and at a temperature of 50° to 68° F., it is supple, tough, extensible but not very elastic. At 112° F., it softens and turns back upon itself, and becomes more and more adhesive and translucent in proportion to the elevation of temperature, undergoing a sort of doughy fusion, which becomes more distinct towards 212° to 230°. Heated beyond this point, it melts, boils and distils, furnishing a pyrogenous oil and carburetted gases.

Pure gutta, like the other two proximate principles, is quickly rendered electrical by friction, and is a bad conductor of heat; it generally floats on water but sinks to the bottom as soon as its pores are filled with this liquid. It is insoluble in alcohol and ether, almost completely insoluble in benzine at 32° F., it is soluble at 77°, and becomes more and more so in proportion as the temperature is raised. The saturated solution at 86° forms itself into a semi-transparent mass when cooled below 32°; alcohol precipitates the gutta from its solution in benzine.

At 32°, spirits of turpentine dissolves very like gutta, whilst it disintegrates and dissolves it readily when hot.

Chloroform and sulphuret of carbon dissolve the gutta in the cold.

After the extraction by means of ether of the two resins interposed in the thin leaves of white gutta percha, leaving the last portion of ether with which they were impregnated to evaporate in the open air, these leaves, enclosed in a flask, experienced, after remaining there for two months at a temperature of from 68° to 82° F., an alteration which appeared to depend on their porosity, the action of the air, and perhaps the ether retained in their pores. However it be, these leaves had then acquired new properties; they were brittle; exhaled a very distinct sharp odour; brought into contact with an excess of anhydrous ether, they were partially dissolved; the soluble portion, obtained by the evaporation of the ether and desiccation at 194° F., was glutinous and translucent; it became opake and hard by cooling down to 14° F.

Sulphuret of carbon, renewed three times in six days, and evaporated each time after two days' contact, left as residue a white flexible leaf. The portion not dissolved, swelled and transparent, did not appear to undergo any change when left in sulphuret of carbon for ten days.

This kind of spontaneous transformation would perhaps become complete if more prolonged; its study will require much time; it will perhaps put us in the way of ascertaining the causes of certain changes observed in some small objects formed of gutta percha. I have already been able to ascertain, that thin leaves, exposed for eight consecutive days to the action of the sun in moist air, were discoloured, and that their substance had become in great part soluble in ether.

Monohydrated sulphuric acid disintegrates, and communicates a brown colour to the pure gutta, with evolution of sulphurous acid; after eight days' contact, the deep brown liquid, on dilution with water, becomes turbid, and furnishes a brown flocculent precipitate. Nitric acid, with a single equivalent of water, attacks the pure gutta with a lively effervescence, and the evolution of orange vapours of hyponitrous acid. Muriatic acid, in its saturated solution, slowly attacks the thin leaves of gutta, giving them a deep brown colour; at the end of eight days it becomes friable. The reaction of muriatic acid establishes an additional distinctive character between this proximate principle and the two others.

Crystalline White Resin.—Obtained pure by means of the operations above described; it presents itself as a light pulverulent mass, apparently opake, which under the microscope exhibits the transparent lamellar crystals. From 32° to 212° F it does not experience any sensible change; its fusion commences at 320°; at 347° to 356° it acquires an oleiform fluidity and complete transparency, without any noticeable colour; it solidifies on cooling, shrinks, which causes it to split, and remains transparent and a little heavier than water.

The crystallized resin is very soluble in spirits of turpentine, in benzine, sulphuret of carbon, ether and chloroform; on the spontaneous evaporation of the two last solvents, it crystallizes in long, narrow, thin, pearly laminæ, forming separate groups radiating from common centres.

Anhydrous alcohol dissolves it pretty readily at the temperature of 167° F.: on cooling, groups of crystals separate, which increase during several days; the cold solution, decanted after crystallization, and left to spontaneous evaporation, yields similar crops of more voluminous lamellæ.

These crystals are not attacked or readily moistened by either cold or boiling water, as is also the case with hot or cold caustic alkaline solutions, ammonia, and the various dilute acids. Monohydrated sulphuric and nitric acids attack it rapidly, producing similar phenomena to those observed in their action upon pure gutta. Muriatic acid, on the contrary, does not act upon the white resin; in several of these characters it approaches to the breane extracted by M. Scribe from the resin of Icica.* It would be well to submit these two principles to a comparative study.

Yellow Resin.—This amorphous transparent resin of a lemon or orange colour according to its thickness, is a little heavier than water, solid, and even hard and brittle, at 32° F.; it gradually becomes more flexible in proportion as the temperature is raised; at 122° F. it becomes pasty; it does not become completely fluid below 212° to 230°. Heated beyond this point, it boils, but then gradually undergoes considerable alteration, becomes brown, and evolves acid fumes and carburets of hydrogen.

This resin strongly retains the alcohol in which it has been dissolved; it is separated from it by heating *in vacuo* to 212° F. until bubbling entirely ceases.

It is soluble in the cold in alcohol, ether, benzine, essential oil or turpentine, sulphuret of carbon and chloroform; all these liquids, when evaporated, leave as residue the amorphous resin.

Dilute acids, concentrated alkaline solutions, and ammonia do not attack the yellow resin. Monohydrated sulphuric and nitric acids act upon it rapidly, producing phenomena analogous to those exhibited with the other two principles. Muriatic acid, even in its saturated solution at 68° F., is without action upon it. But the most remarkable character of this resin is the power of forming, under the circumstances already indicated, those globose crystals covered with a white pellicle of another resin, and offering in their complex form the appearance of opaline spherules.

We see thus that the gutta percha, as it occurs in commerce, consists of three distinctly characterized proximate principles, besides some other matters in small quantities; the most abundant of these principles possesses the properties of the original substance; I give it the name of *pure gutta* or *gutta;* the two other principles are neutral resins.

In order to recal their characteristic properties, I will give the name of *crystalbane* or *albane* to that which is obtained without difficulty in white crystals; and that of *fluavile* to the third, which is yellow, and becomes sensibly fluid at a low temperature.

The commercial varieties which I have examined have given me the following proportions:—

Gutta	75	82
Albane	16	14
Fluavile	6	4

GYPSUM, *Sulphate of Lime, Alabaster, or Paris Plaster.* This substance is found in three geological positions in the crust of the earth; among transition rocks; in the red marl formation; and above the chalk, in the tertiary beds.

1. The alpine gypsums are ranged by M. Brochant among the transition class, and are characterized by the presence of anthracite or stone coal; some of them are white and pure, others gray or yellowish, and mixed with mica, talc, steatite, black oxide of iron, pyrites, compact carbonate of lime, sulphur, and common salt. Examples of such localities are found in the gypsum of *Val-Canaria* at the foot of Saint Gothard, that of Brigg in the upper Valais; of the Grilla in the valley of Chamouni, and of Saint Gervais-les-Bains, near Sallenches in Savoy.

2. The secondary gypsum, or that of the salt mine districts, belongs to the *red ground,* immediately beneath the lias in the order of stratification, and therefore a rock relatively ancient. Near Northwick, the red marl beds above the great deposit of rock salt, are irregularly intersected with gypsum, in numerous laminæ or plates. At Newbiggin in Cumberland, the gypsum lies in red argillaceous marl, between two strata of sandstone; and a mile south of Whitehaven, the subterraneous workings for the alabaster extend

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* Chem. Gaz. vol. iv. p. 151.

30 yards in a direct line; with two or three lateral branches extending about 10 yards, at whose extremities are large spaces where the gypsum is blasted with gunpowder. It is generally compact, forming a regular and conformable bed, with crystals of selenite (crystallized gypsum) in drusy cavities. Gypsum occurs in the red marl in the isle of Axholme, and various other places in Nottinghamshire. In Derbyshire some considerable deposits have been found in the same red sandstone, several of which are mined, as at Chellaston hill, which would exhibit a naked and water-worn rock of gypsum, were it not for a covering of alluvial clay. It appears in general to present itself chiefly in particular patches, occasioning a sudden rise, or an insulated hill, by the additional thickness which it gives to the stratum of the *red ground* in these places. The principal demand for the pure white gypsum, or that faintly streaked with red, is by the potters in Staffordshire, who form their moulds with the calcined powder which it affords; only particularly fine blocks are selected for making alabaster ornaments on the turning lathe. In one of the salt pits near Droitwich, the strata sunk through were vegetable mould, 3 feet; red marl, 35 feet; gypsum, 40 feet; a river of brine, 22 inches; gypsum, 75 feet; a rock of salt, bored into only five, but probably extending much deeper. On the Welsh side of the Bristol Channel, gypsum occurs in the red marl cliffs of Glamorganshire, from Pennarth to Lavernock. No organic remains or metallic minerals have hitherto been found in the gypsum of this formation.

3. The most interesting gypsums in a general point of view, are certainly the tertiary, or those of the plains, or hills of comparatively modern formation. They are characterized by the presence of fossil bones of extinct animals, both *mammifera* and birds, by shells, and a large proportion of carbonate of lime, which gives them the property of effervescing with acids, and the title of limestone gypsums. Such are the gypsums of the environs of Paris, as at the heights of Montmartre, which contain crystallized sulphate of lime in many forms, but most commonly the lenticular and lance-shaped.

Sulphate of lime occurs either as a dense compound without water, and is called *anhydrite* from that circumstance; or with combined water, which is its most ordinary state. Of the latter there are 6 sub-species; sparry gypsum or selenite in a variety of crystalline forms; the foliated granular; the compact; the fibrous; the scaly foliated; the earthy.

The prevailing colour is white, with various shades of gray, blue, red, and yellow. More or less translucent. Soft, sectile, yielding to the nail. Specific gravity 2·2. Water dissolves about one five-hundredth part of its weight of gypsum, and acquires the quality of hardness, with the characteristic selenitic taste. When exposed on red hot coals, it decrepitates, becomes white, and splits into a great many brittle plates. At the heat of a baker's oven, or about 400° Fahr., the combined water of gypsum escapes with a species of ebullition; at a higher temperature the particles get indurated. When rightly calcined and pulverized, gypsum is mixed with water to the consistence of cream, and poured into moulds by the manufacturers of stucco ornaments and statues. A species of rapid crystallization ensues, and the thin paste soon acquires a solid consistence, which is increased by drying the figure in proper stoves. During the consolidation of the plaster, its volume expands into the finest lines of the mould, so as to give a sharp and faithful impression.

The plaster stone of the Paris basin contains about 12 per cent. of carbonate of lime. This body, ground and mixed with water, forms an adhesive mortar much used in building, as it fixes very speedily. Works executed with pure gypsum never become so hard as those made with the calcareous kind: and hence it might be proper to add a certain portion of white slaked lime to our calcined gypsum, in order to give the stucco this valuable property. Coloured stuccos of great solidity are made by adding to a clear solution of glue, any desired colouring tincture, and mixing in the proper quantity of the calcined calcareous gypsum.

The compact, fine-grained gypseous alabaster is often cut into various ornamental figures, such as vases, statuary groups, &c., which take a high polish and look beautiful, but from their softness are easily injured, and require to be kept enclosed within a glass shade.

In America and France, the virtues of gypsum in fertilizing land have been highly extolled, but they have not been realized in the trials made in this kingdom.

Pure gypsum consists of lime 28; sulphuric acid 40; water 18; which are the respective weights of its prime equivalent parts.

M. Gay Lussac, in a short notice, in the *Annales de Chimie* for April 1829, on the setting of gypsum, says that the purest plasters are those that harden least, and that the addition of lime is of no use towards promoting their solidity, nor can the heat proper for boiling gypsum ever expel the carbonic acid gas from the calcareous carbonate present in the gypsum of Montmartre. He conceives that a *hard* plaster-stone having lost its water, will resume more solidity in returning to its first state, than a plaster-stone naturally tender or soft; and that it is the primitive molecular arrangement which is regenerated. See ALABASTER, and STONE ARTIFICIAL.

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HADE signifies, among English miners, the inclination, or deviation from the vertical of any mineral vein.

HAIR (*Cheveu*, *Crin*, Fr.; *Haar*, Germ.) is of all animal products, the one least liable to spontaneous change. It can be dissolved in water only at a temperature somewhat above 230° F., in a Papin's digester, but it appears to be partially decomposed by this heat, since some sulphureted hydrogen is disengaged. By dry distillation, hair gives off several sulphureted gases, while the residuum contains sulphate of lime, common salt, much silica, with some oxyde of iron and manganese. It is a remarkable fact that fair hair affords magnesia, instead of these latter two oxydes. Horse-hair yields about 12 per cent. of phosphate of lime.

Hairs are tubular, their cavities being filled with a fat oil, having the same color with themselves. Hair plunged in chlorine gas, is immediately decomposed and converted into a viscid mass; but when immersed in weak aqueous chlorine, it undergoes no change, except a little bleaching. The application of nitrate of mercury to hairy skins in the process of *secretage*, is explained under PELTRY.

For the dyeing of horse-hair, see the next article.

Living hairs are rendered black by applying to them, for a short time, a paste made by mixing litharge, slaked lime, and bicarbonate of potash, in various proportions, according to the shade of color desired.

We have no recent analysis of hair. Vauquelin found nine different substances in black hair; in red hair, a red oil instead of a greenish-black one.

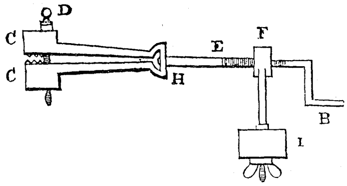
The salts of mercury, lead, bismuth, as well as their oxydes, blacken hair, or make it of a dark violet, by the formation, most probably, of metallic sulphurets.

Hair as an object of manufactures is of two kinds, the *curly* and the *straight*. The former, which is short, is spun into a cord, and boiled in this state, to give it the tortuous springy form. The long straight hair is woven into cloth for sieves, and also for ornamental purposes, as in the damask-hair cloth of chair bottoms. For this purpose the hair may be dyed in the following way.

Forty pounds of tail hair about 26 inches long are steeped in lime water during twelve hours. Then a bath is made with a decoction of 20 pounds of logwood, kept boiling for three hours, after which time the fire is withdrawn from the boiler, and ten ounces of copperas are introduced, stirred about, and the hair is immersed, having been washed from the lime in river water. The hair should remain in this cooling bath for 24 hours, when the operation will be finished. For other colors, see the respective dyes.

The looms for weaving hair differ from the common ones, only in the templet and the shuttle. Two templets of iron must be used to keep the stuff equably, but lightly stretched. These templets, of which one is represented in *fig.* 741, are constructed in the shape of flat pincers; the jaws C C being furnished with teeth inside. A screw D, binds the jaws together, and hinders the selvage from going inwards. Upon the side cross beam of the loom, seen in section at I, a bolt is fixed which carries a nut F at its end, into which a screwed iron rod E enters, on one of whose ends is the handle B. The other extremity of the screw E is adapted by a washer and pin to the back of the pincers at the point H, so that by turning the handle to the right or the left, we draw onwards or push backwards the pincers and the stuff at pleasure. The warp of the web is made of black linen yarn. The weft is of hair, and it is thrown with a long hooked shuttle; or a long rod, having a catch hook at its end. The length of this shuttle is about 3 feet; its breadth half an inch, and its thickness one sixth. It is made of box-wood. The reed is of polished steel; the thread warps are conducted through it in the usual way. The workman passes this shuttle between the hairs of the warp with one hand, when the shed or shuttle way is opened by the treddles; a child placed on one side of the loom presents a hair to the weaver near the selvage, who catches it with the hook of his shuttle, and by drawing it out passes it through the warp. The hairs are placed in a bundle on the side where the child stands, in a chest filled with water to keep them moist, for otherwise they would not have the suppleness requisite to form a web. Each time that a hair is thrown across, the batten is driven home twice. The warp is dressed with paste in the usual way. The hair cloth, after it is woven, is hot calendered to give it lustre.

741



HAIR PENCILS OR BRUSHES for painting. Two sorts are made; those with coarse hair, as that of the swine, the wild boar, the dog, &c., which are attached usually to short wooden rods as handles; these are commonly called *brushes;* and hair pencils, properly so called, which are composed of very fine hairs, as of the minever, the marten, the badger, the polecat, &c. These are mounted in a quill when they are small or of moderate size, but when larger than a quill, they are mounted in white-iron tubes.

The most essential quality of a good pencil is to form a fine point, so that all the hairs without exception may be united when they are moistened by laying them upon the tongue, or drawing them through the lips. When hairs present the form of an elongated cone in a pencil, their point only can be used. The whole difficulty consists after the hairs are cleansed, in arranging them together so that all their points may lie in the same horizontal plane. We must wash the tails of the animals whose hairs are to be used, by scouring them in a solution of alum till they be quite free from grease, and then steeping them for 24 hours in luke-warm water. We next squeeze out the water by pressing them strongly from the root to the tip, in order to lay the hairs as smooth as possible. They are to be dried with pressure in linen cloths, combed in the longitudinal direction, with a very fine-toothed comb, finally wrapped up in fine linen, and dried. When perfectly dry, the hairs are seized with pincers, cut across close to the skin, and arranged in separate heaps, according to their respective lengths.

Each of these little heaps is placed separately, one after the other, in small tin pans with flat bottoms, with the tips of the hair upwards. On striking the bottom of the pan slightly upon a table, the hairs get arranged parallel to each other, and their delicate points rise more or less according to their lengths. The longer ones are to be picked out and made into so many separate parcels, whereby each parcel may be composed of equally long hairs. The perfection of the pencil depends upon this equality; the tapering point being produced simply by the attenuation of the tips.

A pinch of one of these parcels is then taken, of a thickness corresponding to the intended size of the pencil; it is set in a little tin pan, with its tips undermost, and is shaken by striking the pan on the table as before. The root end of the hairs being tied by the fisherman's or seaman's knot, with a fine thread, it is taken out of the pan, and then hooped with stronger thread or twine; the knots being drawn very tight by means of two little sticks. The distance from the tips at which these ligatures are placed, is of course relative to the nature of the hair, and the desired length of the pencil. The base of the pencil must be trimmed flat with a pair of scissors.

Nothing now remains to be done but to mount the pencils in quill or tin-plate tubes as above described. The quills are those of swans, geese, ducks, lapwings, pigeons, or larks, according to the size of the pencil. They are steeped during 24 hours in water, to swell and soften them, and to prevent the chance of their splitting when the hair brush is pressed into them. The brush of hair is introduced by its tips into the large end of the cut quill, having previously drawn them to a point with the lips, when it is pushed forwards with a wire of the same diameter, till it comes out at the other and narrower end of the quill.

The smaller the pencils, the finer ought the hairs to be. In this respect, the manufacture requires much delicacy of tact and experience. It is said that there are only four first-rate hands among all the dexterous pencil-makers of Paris, and that these are principally women.

HALOGENE is a term employed by Berzelius to designate those substances which form compounds of a saline nature, by their union with metals; such are *Bromine, Chlorine, Cyanogene, Fluorine, Iodine. Haloïd* is his name of the salt thereby formed.

HANDSPIKE is a strong wooden bar, used as a lever to move the windlass and capstan in heaving up the anchor, or raising any heavy weights on board a ship. The handle is smooth, round, and somewhat taper; the other end is squared to fit the holes in the head of the capstan or barrel of the windlass.

HARDNESS (*Dureté,* Fr.; *Härte, Festigkeit,* Germ.) is that modification of cohesive attraction which enables bodies to resist any effort made to abrade their surfaces. Its relative intensity is measured by the power they possess of cutting or scratching other substances. The following table exhibits pretty nearly the successive hardnesses of the several bodies in the list:—

Substances.	Hardness.	Specific Gravity.
Diamond from Ormus	20	3·7
Pink diamond	19	3·4
Bluish diamond	19	3·3
Yellowish diamond	19	3·3
Cubic diamond	18	3·2
Ruby	17	4·2
Pale ruby from Brazil	16	3·5
Deep blue sapphire	16	3·8
Ditto, paler	17	3·8
Topaz	15	4·2
Whitish topaz	14	3·5
Ruby spinell	13	3·4
Bohemian topaz	11	2·8
Emerald	12	2·8
Garnet	12	4·4
Agate	12	2·6
Onyx	12	2·6
Sardonyx	12	2·6
Occidental amethyst	11	2·7
Crystal	11	2·6
Cornelian	11	2·7
Green jasper	11	2·7
Reddish yellow do.	9	2·6
Schoerl	10	3·6
Tourmaline	10	3·0
Quartz	10	2·7
Opal	10	2·6
Chrysolite	10	3·7
Zeolite	8	2·1
Fluor	7	3·5
Calcareous spar	6	2·7
Gypsum	5	2·3
Chalk	3	2·7

HARTSHORN, SPIRIT OF, is the old name for water of ammonia.

HATCHING OF CHICKENS. See Incubation, Artificial.

HAT MANUFACTURE. (*L'art de Chapelier*, Fr.; *Hutmacherkunst*, Germ.) Hat is the name of a piece of dress worn upon the head by both sexes, but principally by the men, and seems to have been first introduced as a distinction among the ecclesiastics in the 12th century, though it was not till the year 1400 that it was generally adopted by respectable laymen.

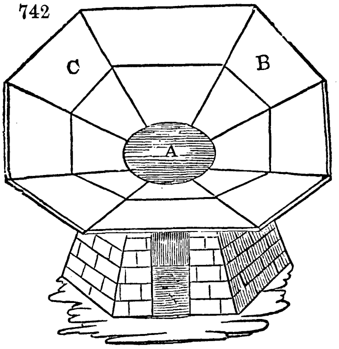
As the art of making common hats does not involve the description of any curious machinery, or any interesting processes, we shall not enter into very minute details upon the subject. It will be sufficient to convey to the reader a general idea of the methods employed in this manufacture.

The materials used in making stuff hats are the furs of hares and rabbits freed from the long hair, together with wool and beaver. The beaver is reserved for the finer hats. The fur is first laid upon a hurdle made of wood or wire, with longitudinal openings; and the operator, by means of an instrument called the bow (which is a piece of elastic ash, six or seven feet long, with a catgut stretched between its two extremities, and made to vibrate by a bowstick), causes the vibrating string to strike and play upon the fur, so as to scatter the fibres in all directions, while the dust and filth descend through the grids of the hurdle.

After the fur is thus driven by the bow from the one end of the hurdle to the other, it forms a mass called a *bat*, which is only half the quantity sufficient for a hat. The bat or *capade* thus formed is rendered compact by pressing it down with the *hardening skin* (a piece of half-tanned leather), and the union of the fibres is increased by covering them with a cloth, while the workman presses them together repeatedly with his hands. The cloth being taken off, a piece of paper, with its corners doubled in, so as to give it a triangular outline, is laid above the bat. The opposite edges of the bat are then folded over the paper, and being brought together and pressed again with the hands, they form a conical cap. This cap is next laid upon another bat, ready hardened, so that the joined edges of the first bat rest upon the new one. This new bat is folded over the other, and its edges joined by pressure as before; so that the joining of the first conical cap is opposite to that of the second. This compound bat is now wrought with the hands for a considerable time upon the hurdle between folds of linen cloth, being occasionally sprinkled with clear water, till the hat is basined or rendered tolerably firm.

The cap is now taken to a wooden receiver, like a very flat mill-hopper, consisting of eight wooden planes, sloping gently to the centre, which contains a kettle filled with water acidulated with sulphuric acid. The technical name of this vessel is the *battery*. It consists of a kettle A; and of the planks, B C, which are sloping planes, usually eight in number, one being allotted to each workman. The half of each plank next the kettle is made of lead, the upper half of mahogany. In this liquor the hat is occasionally dipped, and wrought by the hands, or sometimes with a roller, upon the sloping planks. It is thus fulled or thickened during four or five hours; the knots or hard substances are picked out by the workman, and fresh felt is added by means of a wet brush to those parts that require it. The beaver is applied at the end of this operation. In the manufacture of beaver hats, the grounds of beer are added to the liquor in the kettle.

742



Stopping, or thickening the thin spots, seen by looking through the body, is performed by daubing on additional stuff with successive applications of the hot acidulous liquor from a brush dipped into the kettle, until the body be sufficiently shrunk and made uniform. After drying, it is stiffened with varnish composition rubbed in with a brush; the inside surface being more copiously imbued with it than the outer; while the brim is peculiarly charged with the stiffening.

When once more dried, the body is ready to be *covered*, which is done at the *battery*. The first cover of beaver or napping, which has been previously *bowed*, is strewed equably over the body, and patted on with a brush moistened with the hot liquor, until it gets incorporated; the cut ends towards the root, being the points which spontaneously intrude. The body is now put into a coarse hair cloth, then dipped and rolled in the hot liquor, until the root ends of the beaver are thoroughly worked in. This is technically called rolling off, or *roughing*. A strip for the brim, round the edge of the inside, is treated in the same way; whereby every thing is ready for the second cover (of beaver), which is incorporated in like manner; the rolling, &c. being continued, till a uniform, close, and well-felted hood is formed.

The hat is now ready to receive its proper shape. For this purpose the workman turns up the edge or brim to the depth of about 1½ inch, and then returns the point of the cone back again through the axis of the cap, so as to produce another inner fold of the same depth. A third fold is produced by returning the point of the cone, and so on till the point resembles a flat circular piece having a number of concentric folds. In this state it is laid upon the plank, and wetted with the liquor. The workman pulls out the point with his fingers, and presses it down with his hand, turning it at the same time round on its centre upon the plank, till a flat portion, equal to the crown of the hat, is rubbed out. This flat crown is now placed upon a block, and, by pressing a string called a *commander*, down the sides of the block, he forces the parts adjacent to the crown, to assume a cylindrical figure. The brim now appears like a puckered appendage round the cylindrical cone; but the proper figure is next given to it, by working and rubbing it. The body is rendered waterproof and stiff by being imbued with a varnish composed of shellac, sandarach, mastic, and other resins dissolved in alcohol or naptha.

The hat being dried, its nap is raised or loosened with a wire brush or card, and sometimes it is previously pounced or rubbed with pumice, to take off the coarser parts, and afterwards rubbed over with seal-skin. The hat is now tied with pack-thread upon its block, and is afterwards dyed. See HAT-DYEING, *infra*.

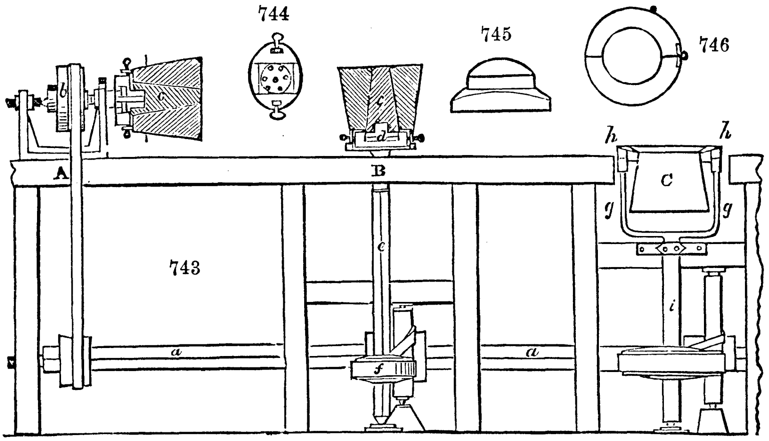
The dyed hats are now removed to the stiffening shop. Beer grounds are next applied on the inside of the crown, for the purpose of preventing the glue from coming through; and when the beer grounds are dried, glue (gum Senegal is sometimes used) a little thinner than that used by carpenters, is laid with a brush on the inside of the crown, and the lower surface of the brim.

The hat is then softened by exposure to steam, on the steaming basin, and is brushed and ironed till it receives the proper gloss. It is lastly cut round at the brim by a knife fixed at the end of a gauge, which rests against the crown. The brim, however, is not cut entirely through, but is torn off so as to leave an edging of beaver round the external rim of the hat. The crown being tied up in a gauze paper, which is neatly ironed down, is then ready for the last operations of lining and binding.

The furs and wools of which hats are manufactured contain, in their early stage of preparation, *hemps* and *hairs,* which must be removed in order to produce a material for the better description of hats. This separation is effected by a sort of winnowing machine, which wafts away the finer and lighter parts of the furs and wools from the coarser. Messrs. Parker and Harris obtained a patent in 1822 for the invention and use of such an apparatus, whose structure and functions may be perfectly understood, from its analogy to the blowing and scutching machine of the cotton manufacture; to which I therefore refer my readers.

I shall now proceed to describe some of the recent improvements proposed in the manufacture of hats, but their introduction is scarcely possible, on account of the perfectly organized combination which exists among journeyman hatters throughout the kingdom, by which the masters are held in a state of complete servitude, having no power to take a single apprentice into their works beyond the number specified by the *Union,* nor any sort of machine which is likely to supersede hand labor in any remarkable degree. Hence the hat trade is, generally speaking, unproductive to the capitalist, and incapable of receiving any considerable development. The public of a free country like this, ought to counteract this disgraceful state of things, by renouncing the wear of stuff hats, a branch of the business entirely under the control of this despotic *Union,* and betake themselves to the use of silk hats, which, from recent improvements in their fabric and dyeing, are not a whit inferior to the beaver hats, in comfort, appearance, or durability, while they may be had of the best quality for one fourth part of their price.

The annexed figures represent Mr. Ollerenshaw's machine, now generally employed or ironing hats. *Fig.* 743 is the frame-work or standard upon which three of these lathes are mounted, as A, B, C. The lathe A is intended to be employed when the crown of the hat is to be ironed. The lathe B, when the flat top, and the upper side of the brim is ironed, and lathe C, when its under side is ironed; motion being given to the whole by means of a band passing from any first mover (as a steam-engine, water-wheel, &c.) to the drum on the main shaft *a a.* From this drum a strap passes over the rigger b, which actuates the axle of the lathe A. On to this lathe a sort of chuck is screwed, and to the chuck the block *c* is made fast by screws, bolts, or pins. This block is represented in section, in order to show the manner in which it is made, of several pieces held fast by the centre wedge-piece, as seen at *fig.* 744.



The hat-block being made to turn round with the chuck, at the rate of about twenty turns per minute, but in the opposite direction to the revolution of an ordinary turning lathe, the workman applies his hot iron to the surface of the hat, and thereby smooths it, giving a beautiful glossy appearance to the beaver; he then applies a plush cushion, and rubs round the surface of the hat while it is still revolving. The hat, with its block, is now removed to the lathe B, where it is placed upon the chuck *d,* and made to turn in a horizontal direction, at the rate of about twenty revolutions per minute, for the purpose of ironing the flat-top of the crown. This lathe B moves upon an upright shaft *e,* and is actuated by a twisted band passing from the main shaft, round the rigger *f*. In order to iron the upper surface of the brim, the block *c* is removed from the lathe, and taken out of the hat, when the block *fig*. 745, is mounted upon the chuck *d*, and made to turn under the hand of the workman, as before.

The hat is now to be removed to the lathe c, where it is introduced in an inverted position, between the arms *g g* supporting the rim *h h*, the top surface of which is shown at *fig*. 746. The spindle *i* of the lathe turns by similar means to the last, but slower; only ten turns per minute will be sufficient. The workman now smooths the under side of the brim, by drawing the iron across it, that is, from the centre outwards. The hat is then carefully examined, and all the burs and coarse hairs picked out, after which the smoothing process is performed as before, and the dressing of the hat is complete.

Messrs. Gillman and Wilson, of Manchester, obtained a patent in 1823, for a peculiar kind of fabric to be made of cotton, or a mixture of cotton and silk, for the covering of hats and bonnets, in imitation of beaver. The foundation of the hat may be of felt, hemp, wool, which is to be covered by the patent fabric. This debased article does not seem to have got into use; cotton, from its want of the felting property and inelasticity, being very ill-adapted for making hat-stuff.

A more ingenious invention of John Gibson, hatter, in Glasgow, consisting of an elastic fabric of whalebone, was made the subject of a patent, in June, 1824. The whalebone, being separated into threads no larger than hay stalks, is to be boiled in some alkaline liquid for removing the oil from it, and rendering it more elastic. The longest threads are to be employed for warp, the shorter for weft; and are to be woven in a hair-cloth loom. This fabric is to be passed between rollers, after which it is fit to be cut out into forms for making hats and bonnets, to be sewed together at the joints, and stiffened with a preparation of resinous varnishes, to prevent its being acted upon by perspiration or rain. A very considerable improvement in the lightness and elasticity of silk hats has been the result of this invention.

The foundation of men's hats, upon whose outside the beaver, down, or other fine fur is laid to produce a nap, is, as I have described, usually made of wool felted together by hand, and formed first into conical caps, which are afterwards stretched and moulded upon blocks to the desired shape. Mr. Borradaile, of Bucklersbury, obtained a patent in November, 1825, for a machine, invented by a foreigner, for setting up hat bodies, which seems to be ingeniously contrived; but I shall decline describing it, as it has probably not been suffered by the *Union* to come into practical operation, and as I shall presently give the details of another later invention for the same purpose.

Silk hats, for several years after they were manufactured, were liable to two objections; first, the body or shell over which the silk covering is laid, was, from its hardness, apt to hurt the head; second, the edge of the crown being much exposed to blows, the silk nap soon got abraded, so as to lay bare the cotton foundation, which is not capable of taking so fine a black dye as the silk; whence the hat assumed a shabby appearance. Messrs. Mayhew and White of London, hat-manufacturers, proposed in their patent of February, 1826, to remedy these defects, by making the hat body of stuff or wool, and relieving the stiffness of the inner part round the brim, by attaching a coating of beaver upon the under side of the brim, so as to render the hat pliable. Round the edge of the tip or crown, a quantity of what is called stop wool is to be attached by the ordinary operation of bowing, which will render the edge soft and elastic. The hat is to be afterwards dyed of a good black color, both outside and inside; and being then properly stiffened and blocked, is ready for the covering of silk.

The plush employed for covering silk hats, is a raised nap or pile woven usually upon a cotton foundation; and the cotton, being incapable of receiving the same brilliant black dye as the silk, renders the hat apt to turn brown whenever the silk nap is partially worn off. The patentees proposed to counteract this evil, by making the foundation of the plush entirely of silk. To these two improvements, now pretty generally introduced, the present excellence of the silk hats may be, in a good measure, ascribed.

The apparatus above alluded to, for making the foundations of hats by the aid of mechanism, was rendered the subject of a patent, by Mr. Williams, in September, 1826; but I fear it has never obtained a footing, nor even a fair trial in our manufactures, on account of the hostility of the operatives to all labor-saving machines.

Fig. 747 is a side view of the carding engine, with a horizontal or plan view of the lower part of the carding machine, showing the operative parts of the winding apparatus, as connected to the carding engine. The doffer cylinder is covered with fillets of wire cards, such as are usually employed in carding engines, and these fillets are divided into two, three, or more spaces extending round the periphery of the cylinder, the object of which division is to separate the sliver into two, three, or more breadths, which are to be conducted to, and wound upon distinct blocks, for making so many separate hats or caps.

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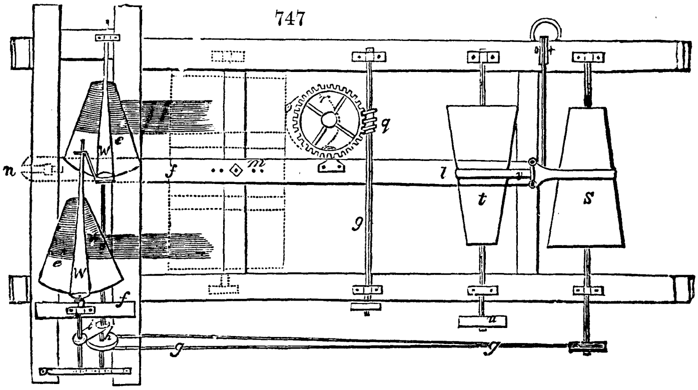
The principal cylinder of the carding engine is made to revolve by a rigger upon its axle, actuated by a band from any first mover as usual, and the subordinate rollers or cylinders belonging to the carding engine, are all turned by pulleys, and bands, and gear, as in the ordinary construction.

747



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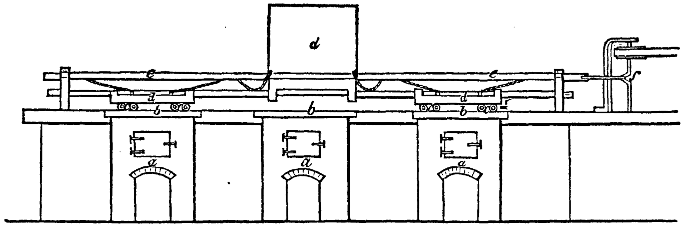


The wool or other material is supplied to the feeding cloth, and carried through the engine to the doffer cylinder, as in other carding engines; the doffer comb is actuated by a revolving crank in the common way, and by means of it the slivers are taken from the doffer cylinder, and thence received on to the surfaces of the blocks *e e*. These blocks, of which two only are shown to prevent confusion, are mounted upon axles, supported by suitable bearings in a carriage *f f*, and are made to revolve by means of a band *g g*, leading from a pulley on the axle of a conical drum beneath. The band *g* passes over a pulley *h*, affixed to the axle of one of the blocks, while another pulley *i*, upon the same axle, gives motion, by means of a band, to as many other blocks as are adapted to the machine.

As it is necessary, in winding the slivers on to the blocks, to cross them in different directions, and also to pass the sliver over the hemispherical ends of the blocks, in order that the wool or other material may be uniformly spread over the surface in forming the cap or hood for the shell or foundation of the intended hat, the carriage *f*, with the blocks, is made to traverse to and fro in lateral directions upon rollers at each end.

This alternating motion of the carriage is caused by a horizontal lever *l l* (seen in the horizontal view *fig.* 747), moving upon a fulcrum pin at *m*, which lever is attached to the carriage at one extremity *n*, and at the other end has a weighted cord which draws the side of this lever against a cam wheel *o*. This cam is made to revolve by means of a band and pulley, which turns the shaft and endless screw *q*, and this endless screw taking into a toothed wheel *r*, on the axle of the cam *o*, causes the cam to revolve, the periphery of which cam running against a friction roller on the side of the lever *l*, causes the lever to vibrate, and the carriage *f f* attached to it, to traverse to and fro upon the supporting rollers, as described. By these means the slivers are laid in oblique directions (varying as the carriage traverses), over the surface of the blocks.

The blocks being conically formed, or of other irregular figures, it is necessary, in order to wind the slivers with uniform tension, to vary their speed according to the diameter of that part of the block which is receiving the sliver. This is effected by giving different velocities to the pulley on the axle of the conical drum *s*, corresponding with *e*. There is a similar conical drum *t*, placed in a reverse position in the lower part of the frame, which is actuated by a band from any convenient part of the machine passing over a pulley *u*, upon the axle of *t*. From the drum *t*, to the drum *s*, there is a band *v*, which is made to slide along the drums by the guidance of two rollers at the end of the lever *l*.

It will now be seen that when the larger diameter of the cam wheel *o* forces the lever outwards, the band *v* will be guided on to the smaller part of the conical drum *t* and the larger part of *s*, consequently the drum *s* will at this time receive its slowest motion, and the band *g* will turn the blocks slower also; the reverse end of the lever *l* having, by the same movement, slidden the carriage into that position which causes the slivers to wind upon the larger diameter of the blocks.

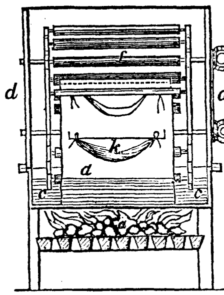
When the smaller diameter of the cam is acting against the side of the lever, the weighted cord draws the end of the lever to the opposite side, and the band *v* will be guided on to the larger part of the cord *t*, and the smaller part of the cone *s*; consequently, the quicker movement of the band *g* will now cause the blocks *e e* to revolve with a corresponding speed. The carriage *f* will also be moved upon its rollers, to the reverse side, and the sliver of wool or other material be now wound upon the smaller parts and ends of the blocks, at which time the quicker rotation of the blocks is required. It may be here observed, that the cam wheel *o* should be differently formed according to the different shaped blocks employed, so as to produce the requisite movements of the lever and carriage suited thereto.

It only remains to state, that there are two heavy conical rollers *w w*, bearing upon the peripheries of the blocks *e e*, which turn loosely upon their axles by the friction of contact, for the purpose of pressing the slivers of wool or other material on the blocks as it comes from the doffer cylinder of the carding engine, and when the blocks have been coated with a sufficient quantity of the sliver, the smaller end of the pressing rollers is to be raised, while the cap is withdrawn from the block. The process being continued as before, the formation of other bodies or caps is effected in the manner above described.

After the caps or bodies of hats, &c. are formed in the above described machine, they are folded in wet cloths, and placed upon heated plates, where they are rolled under pressure, for the purpose of being hardened. *Fig.* 748 represents the front of three furnaces *a a a*, the tops of which are covered with iron plates *b b b*. Upon these plates, which are heated by the furnace below, or by steam, the bodies wrapped in the wet cloths *c c c*, are placed, and pressed upon by the flaps or covers *d d d*, sliding upon guide rods, to which flaps a traversing motion is given, by means of chains attached to an alternating bar *e e*. This bar is moved by a rotatory crank *f*, which has its motion by pulleys from any actuating power. When any one of the flaps is turned up to remove the bodies from beneath, the chains hang loosely, and the flap remains stationary.

These caps or hat bodies, after having been hardened in the manner above described, may be felted in the usual way by hand, or they are felted in a fulling mill, by the usual process employed for milling cloths, except that the hat bodies are occasionally taken out of the fulling mill, and passed between rollers, for the purpose of rendering the felt more perfect.

749



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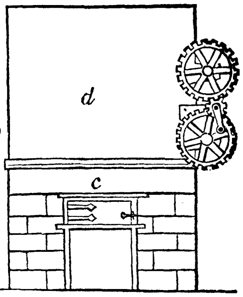
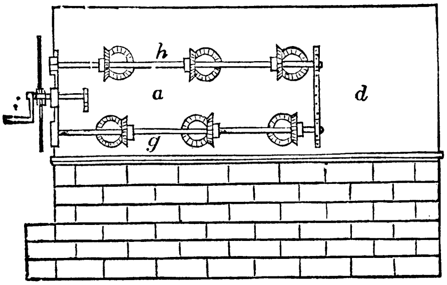


Mr. Carey, of Basford, obtained a patent in October, 1834, for an invention of certain machinery to be employed in the manufacture of hats, which is ingenious, and seems to be worthy of notice in this place. It consists in the adaptation of a system of rollers, forming a machine, by means of which the operation of roughing or plaiting of hats may be performed; that is, the beaver or other fur may be made to attach itself, and work into the felt or hat body, without the necessity of the ordinary manual operations.

The accompanying drawings represent the machine in several views, for the purpose of showing the construction of all its parts. *Fig.* 749 is a front elevation of the machine; *fig.* 750 is a side elevation of the same; *fig.* 751 is a longitudinal section of the machine; and *fig.* 752 is a transverse section; the similar letters indicating the same parts in all the figures.

Upon a brick or other suitable base a furnace or fire-place *a*, is made, having a descending flue *b*, for the purpose of carrying away the smoke. A pan or shallow vessel *c c*, formed of lead, is placed over the furnace; which vessel is intended to contain a sour liquor, as a solution of vitriolic acid and water. On the edge of this pan is erected a wooden casing *d d d*, which encloses three sides, leaving the fourth open for the purpose of obtaining access to the working apparatus within. A series of what may be termed lantern rollers, *e e e*, is mounted on axles turning in the side casings; and another series of similar lantern rollers, *f f f*, is in like manner mounted above. These lantern rollers are made to revolve by means of bevel pinions, fixed on the ends of their axles, which are turned by similar bevel wheels on the lateral shafts *g* and *h*, driven by a winch *i*, and gear, as shown in *figs.* 749 and 750.

750



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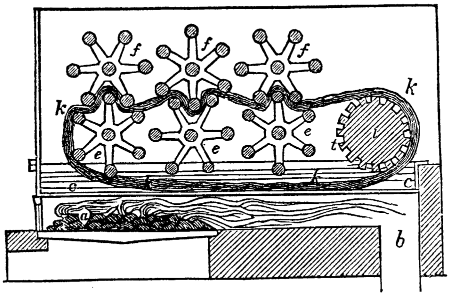


Having prepared the bodies of the hats, and laid upon their surfaces the usual coatings of beaver, or other fur, when so prepared they are to be placed between hair cloths, and these hair cloths folded within a canvass or other suitable wrapper. Three or more hats being thus enclosed in each wrapper, the packages are severally put into bags or pockets in an endless band of sack-cloth, or other suitable material; which endless band is extended over the lantern rollers in the machine.

In the first instance, for the purpose of merely attaching the furs to the felts (which is called slicking, when performed by hand), Mr. Carey prefers to pass the endless band *k k k*, with the covered hat bodies, over the upper series *f f f*, of the lantern rollers, in order to avoid the inconvenience of disturbing the fur, which might occur from subjecting them to immersion in the solution contained in the pan, before the fur had become attached to the bodies.

After this operation of slicking has been effected, he distends the endless band *k k k*, over the lower series of lantern rollers *e e e*, and round a carrier roller *l*, as shown in *fig.* 751; and having withdrawn the hat bodies for the purpose of examining them, and changing their folds, he packs them again in a similar way in flannel, or other suitable cloths, and introduces them into the pockets or bags of the endless bands, as before.

On putting the machinery in rotatory motion in the way described, the hats will be carried along through the apparatus, and subjected to the scalding solution in the pan, as also to the pressure, and to a tortuous action between the ribs of the lantern rollers, as they revolve, which will cause the ends of the fur to work into the felted bodies of the hats, and by that means permanently to attach the nap to the body; an operation which, when performed by hand, is called rolling off.

The improved stiffening for hat bodies proposed by Mr. Blades, under his patent of January, 1828, consists in making his solution of shellac in an alkaline ley, instead of spirits of wine, or pyroxylic spirit, vulgarly called naptha.

He prepares his water-proof stiffening by mixing 18 pounds of shellac with 1½ pounds of salt of tartar (carbonate of potash), and 5½ gallons of water. These materials are to be put into a kettle, and made to boil gradually until the lac is dissolved; when the liquor will become as clear as water, without any scum upon the top, and if left to cool, will have a thin crust upon its surface of a whitish cast, mixed with the light impurities of the gum. When this skin is taken off, the hat body is to be dipped into the mixture in a cold state, so as to absorb as much as possible of it; or it may be applied with a brush or sponge. The hat body, being thus stiffened, may stand till it become dry, or nearly so; and after it has been brushed, it must be immersed in very dilute sulphuric or acetic acid, in order to neutralize the potash, and cause the shellac to set. If the hats are not to be napped immediately, they may be thrown into a cistern of pure water, and taken out as wanted.

Should the hat bodies have been worked at first with sulphuric acid (as usual), they must be soaked in hot water to extract the acid, and dried before the stiffening is applied care being taken that no water falls upon the stiffened body, before it has been immersed in the acid.

This ingenious chemical process has not been, to the best of my knowledge, introduced into the hat manufacture. A varnish made by dissolving shellac, mastic, sandarach, and other resins in alcohol, or the naptha of wood vinegar, is generally employed as the stiffening and water-proof ingredient of hat bodies. A solution of caoutchouc is often applied to whalebone and horse-hair hat bodies.

The following recipe has been prescribed as a good composition for stiffening hats; four parts of shellac, one part of mastic, one half of a part of turpentine, dissolved in five parts of alcohol, by agitation and subsequent repose, without the aid of heat. This stiffening varnish should be applied quickly to the body or foundation with a soft oblong brush, in a dry and rather warm workshop; the hat being previously fitted with its inside turned outwards upon a block. The body must be immediately afterwards taken off, to prevent adhesion.

Hat-Dyeing.—The ordinary bath for dyeing hats, employed by the London manufacturers, consists, for 12 dozen, of—

144 pounds of logwood;
12 pounds of green sulphate of iron, or copperas;
7½ pounds of verdigris.

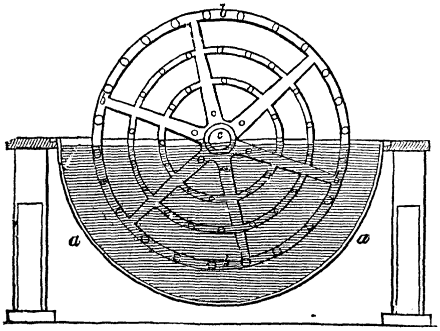
The copper is usually made of a semi-cylindrical shape, and should be surrounded with an iron jacket or case, into which steam may be admitted, so as to raise the temperature of the interior bath to 190° F., but no higher, otherwise the heat is apt to affect the stiffening varnish, called the gum, with which the body of the hat has been imbued. The logwood having been introduced and digested for some time, the copperas and verdigris are added in successive quantities, and in the above proportions, along with every successive two or three dozens of hats, suspended upon the dipping machine. Each set of hats, after being exposed to the bath with occasional airings during 40 minutes, is taken off the pegs, and laid out upon the ground to be more completely blackened by the peroxydizement of the iron with the atmospheric oxygen. In 3 or 4 hours the dyeing is completed. When fully dyed, the hats are well washed in running water.

Mr. Buffum states that there are four principal objects accomplished by his patent invention for dyeing hats.

1. in the operation;
2. the production of a better color;
3. the prevention of any of the damages to which hats are liable in the dyeing;
4. the accomplishment of the dyeing process in a much shorter time than by the usual methods, and consequently lessening the injurious effects of the dye-bath upon the texture of the hat.

Fig. 753 shows one method of constructing the apparatus. *a a* is a semi-cylindrical shaped copper vessel, with flat ends, in which the dyeing process is carried on. *b b b* is a wheel with several circular rims mounted upon arms, which revolve upon an axle *c*. In the face of these rims a number of pegs or blocks are set at nearly equal distances apart, upon each of which pegs or blocks it is intended to place a hat, and as the wheel

753



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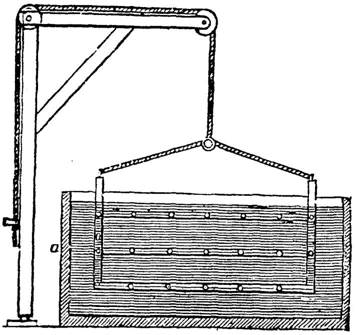

revolves, to pass it into and out of the dyeing liquor in the vat or copper. This wheel may be kept revolving with a very slow motion, either by gear connecting its axle, c, with any moving power, or it may be turned round by hand, at intervals of ten minutes; whereby the hats hung upon the pegs, will be alternately immersed for the space of ten minutes in the dyeing liquor, and then for the same space exposed to the atmospheric air. In this way, the process of dyeing, it is supposed, may be greatly facilitated and improved, as the occasional transition from the dye vat into the air, and from the air again into the bath, will enable the oxygen of the atmosphere to strike the dye more perfectly and expeditiously into the materials of which the hat is composed, than by a continued immersion in the bath for a much longer time.

A variation in the mode of performing this process is suggested, and the apparatus *fig.* 754 is proposed to be employed. *a a* is a square vat or vessel containing the dyeing liquor; *b b* is a frame or rack having a number of pegs placed in it for hanging the hats upon, which are about to be dyed, in a manner similar to the wheel above described. This frame or rack is suspended by cords from a crane, and may in that way be lowered down with the hats into the vat, or drawn up and exposed in the air; changes which may be made every 10 or 20 minutes.

I have seen apparatus of this kind doing good work in the hat-dyeing manufactories of London, that being a department of the business with which the Union has not thought it worth their while to interfere.

Mr. William Hodge's patent improvements in hat dyeing, partly founded upon an invention of Mr. Bowler, consist, first in causing every alternate frame to which the suspenders or blocks are to be attached, to slide in and out of grooves, for the purpose of more easily removing the said suspenders when required. *Fig.* 755 represents the improved dyeing frame, consisting of two circular rims, *a a*, which are connected together at top and bottom, by three fixed perpendicular bars or the frame-work *b b b*. Two other perpendicular frames *c c*, similar to the former, slide in grooves, *d d d d*, fixed to the upper and lower rims. These grooves have anti-friction rollers in them, for the purpose of making the frames *c c*, to slide in and out more freely. The suspenders or substitutes for blocks, by these means, may be more easily got at by drawing out the frames *c c*, about half way, when the suspenders, which are attached to the frames with the hats upon them, may be easily reached, and either removed or altered in position; and when it is done on one side, the sliding frame may be brought out on the other, and the remaining quantity of "suspenders" undergo the same operation.

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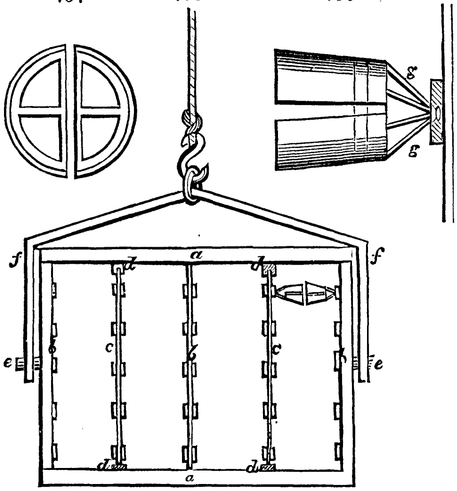

The patentee remarks, that it is well known to all hat dyers, that after the hats have been in the dyeing liquor some time, they ought to be taken out and exposed to the action of the atmospheric air, when they are again immersed in the copper, that part of the hat which was uppermost in the first immersion, being placed downwards in the second. This is done for the purpose of obtaining a uniform and regular dye. The patentee's mode of carrying this operation into effect, is shown in the figure: *e e* are pivots for the dyeing-frame to turn upon, which is supported by the arms *f*, from a crane above. The whole apparatus may be raised up or lowered into the copper by means of the crane or other mechanism. When the dyeing-frame is raised out of the copper, the whole of the suspenders or blocks are reversed, by turning the apparatus over upon the pivots *e e*, and thus the whole surfaces of the hats are equally acted upon by the dyeing material.

It should be observed, that when the dyeing-frame is raised up out of the copper, it should be tilted on one side, so as to make all the liquor run out of the hats, as also to cause the rims of the hats to hang down, and not stick to the body of the hat, or leave a bad place or uneven dye upon it. The second improvement described by the patentee is the construction of "suspenders," to be substituted instead of the ordinary blocks.

These "suspenders" are composed of thin plates of copper, bent into the required form, that is, nearly resembling that of a hat block, and made in such a manner as to be capable of contraction and expansion to suit different sized hats, and keep them distended, which may be altered by the workmen at pleasure, when it is required to place the hats upon them, or remove them therefrom. The dyeing-frame at *fig.* 755 is shown with only two of these "suspenders," in order to prevent confusion. One of these suspenders is represented detached at *fig.* 756, which exhibits a side view; and *fig.* 757 a front view of the same. It will be seen by reference to the figure, that the suspenders consist of two distinct parts, which may be enlarged or collapsed by a variety of means, and which means may be suggested by any competent mechanic. The two parts of the suspenders are proposed to be connected together by arms *g g*, and at the junction of these arms a key is connected for turning them round when required. It will be seen on reference to the front view, *fig.* 757, that the "suspenders" or substitutes for blocks, are open at the top or crown part of the hat; this is for the purpose of allowing the dyeing liquor to penetrate.

From the mixture of copperas and verdigris employed in the hat-dye, a vast quantity of an ochreous muddy precipitate results, amounting to no less than 25 per cent. of the weight of the copperas. This iron mud forms a deposite upon the hats, which not only corrodes the fine filaments of the beaver, but causes both them and the felt stuff to turn speedily of a rusty brown. There is no process in the whole circle of our manufactures so barbarous as that of dyeing stuff hats. No ray of chemical science seems hitherto to have penetrated the dark recesses of their dye shops. Some hatters have tried to remove this corrosive brown ochre by a bath of dilute sulphuric acid, and then counteract the evil effect of the acid upon the black dye by an alkaline bath; but with a most unhappy effect. Hats so treated are most deceptious and unprofitable; as they turn of a dirty brown hue, when exposed for a few weeks to sunshine and air

Hats. The body of a beaver hat is made of fine wool and coarse fur mixed and felted together, then stiffened and shaped; the covering consists of a coat of beaver fur felted upon the body. Cheap hats have their bodies made of coarse wool, and their coverings of coarse fur or fine wool. The body or foundation of a good beaver hat, is at present made of 8 parts of rabbit's fur, 3 parts of Saxony wool, and 1 part of lama, vicunia, or red wool. About two ounces and a half of the above mixture are sufficient for one hat, and these are placed in the hands of the *bower;* his tool is a bow or bent ashen staff, from 5 to 7 feet long, having a strong catgut string stretched over a bridge at each end, and suspended at its middle by a cord to the ceiling, so as to hang nearly level with the work-bench, and a small space above it. The wool and coarser fur are laid in their somewhat matted state upon this bench, when the bower, grasping the bent rod with his left hand, and *by means of a small wooden catch plucking the string with his right,* makes it vibrate smartly against the fibrous substances, so as to disentangle them, toss them up in the air, and curiously arrange themselves in a pretty uniform layer or fleece. A skilful bower is a valuable workman. The bowed materials of one hat are spread out and divided into two portions, each of which is compressed, first with a light wicker frame, and next under a piece of oil cloth or leather, called a hardening skin, till by pressing the hands backward and forward all over the skin, the filaments are linked together by their serrations into a somewhat coherent fleece of a triangular shape. The two halves or "bats" are then formed into a cap; one of them is covered in its middle with a 3-cornered piece of paper, smaller than itself, so that its edges may be folded over the paper, and by overlapping each other a little, form a complete envelope to the paper; the junctions are then partially felted together by rubbing them hard, care being taken to keep the base of the triangle open by means of the paper; the second bat being made to enclose the first by a similar process of folding and friction This double cap, with its enclosed sheet of paper, is next rolled up in a damp cloth and kneaded with the hands in every direction, during which it is unfolded and creased up again in different forms, whereby the two layers get thoroughly incorporated into one body; thus, on withdrawing the paper, a hollow cone is obtained. The above operations have been partially described in the body of the Dictionary, and the remaining steps in making a hat are there sufficiently detailed.

In a great hat factory women are employed, at respectable wages, in plucking the beaver skins, cropping off the fur, sorting various qualities of wool, plucking and cutting rabbit's fur, shearing the nap of the blocked hat, picking out unseemly filaments of fur, and in trimming the hats; that is, lining and binding them.

The annual value of the hats manufactured at present in the United Kingdom is estimated at 3,000,000*l.* sterling. The quantity exported in 1840, was 22,522 dozens, valued at 81,583*l.*

With regard to the *stiffening* of hats, I have been furnished by a skilful operator with the following valuable information: "All the solutions of gums which I have hitherto seen prepared by hatters, have not been perfect, but, in a certain degree, a mixture, more or less, of the gums, which are merely suspended, owing to the consistency of the composition. When this is thinned by the addition of spirit, and allowed to stand, it lets fall a curdy-looking sediment, and to this circumstance may be ascribed the frequent breaking of hats. My method of proceeding is, first to dissolve the gums by agitation in twice the due quantity of spirits, whether of wood or wine, and then, after complete solution, draw off one-half the spirit in a still, so as to bring the stiffening to a proper consistency. No sediment subsequently appears on diluting this solution, however much it may be done.

"Both the spirit and alkali stiffenings for hats made by the following two recipes, have been tried by some of the first houses in the trade, and have been much approved of:—

Spirit Stiffening.

7 pounds of orange shellac.
2 pounds of gum sandarac.
4 ounces of gum mastic.
Half a pound of amber rosin.
1 pint of solution of copal.
1 gallon of spirit of wine or wood naphtha.

"The shellac, sandarac, mastic, rosin, are dissolved in the spirit, and the solution of copal is added last.

Alkali Stiffening.

7 pounds of common block shellac.
1 pound of amber rosin.
4 ounces of gum thus.
4 ounces of gum mastic.
6 ounces of borax.
Half a pint of solution of copal.

"The borax is first dissolved in a little warm water (say 1 gallon); this alkaline liquor is now put into a copper pan (heated by steam), together with the shellac, rosin, thus, and mastic, and allowed to boil for some time, more warm water being added occasionally until it is of a proper consistence; this may be known by pouring a little on a cold slab somewhat inclined, and if the liquor runs off at the lower end, it is sufficiently fluid; if, on the contrary, it set before it reaches the bottom, it requires more water. When the whole of the gums seem dissolved, half a pint of wood naphtha must be introduced, and the solution of copal; then the liquor must be passed through a fine sieve, and it will be perfectly clear and ready for use. This stiffening is used hot. The hat bodies, before they are stiffened, should be steeped in a weak solution of soda in water, to destroy any acid that may have been left in them (as sulphuric acid is used in the making of the bodies). If this is not attended to, should the hat body contain any acid when it is dipped into the stiffening, the alkali is neutralized, and the gums consequently precipitated. After the body has been steeped in the alkaline solution, it must be perfectly dried in the stove before the stiffening is applied; when stiffened and stoved it must be steeped all night in water, to which a small quantity of sulphuric acid has been added; this *sets* the stiffening in the hat body, and finishes the process. A good workman will stiffen 15 or 16 dozen hats a day. If the proof is required cheaper, more shellac and rosin must be introduced."

HEALDS, is the harness for guiding the warp threads in a loom; that is, for lifting a certain number of them alternately to open the shed, and afford passage to the decussating weft threads of the shuttle. See WEAVING.

HEARTH; (*Foyer*, Fr.; *Heerde*, Germ.) is the flat or hollow space in a smelting furnace upon which the ore and fluxes are subjected to the influence of flame. See COPPER, IRON, METALLURGY, &c.

HEAT, is that power or essence called caloric, the discussion of whose habitudes with the different kinds of matter belongs to the science of chemistry.

HEAT-REGULATOR. The name given by M. Bonnemain to an ingenious apparatus for regulating the temperature of his incubating stove rooms. See INCUBATION, ARTIFICIAL, for the manner of applying the Heat-Regulator.

The construction of the regulator is founded upon the unequal dilatations of different metals by the same degree of heat. A rod of iron *x*, *fig.* 758., is tapped at its lower end into a brass nut *y*, enclosed in a leaded box or tube, terminated above by a brass collet *z*. This tube is plunged into the water of the boiler, alongside of the smoke-pipe. (*Fig.* 759. is a bird's-eye view of the dial, &c.) The expansion of the lead being more than the iron for a like degree of temperature, and the rod enclosed within the tube being less easily warmed, whenever the heat rises to the desired pitch, the elongation of the tube puts the collet *z* in contact with the heel *a*, of the bent lever

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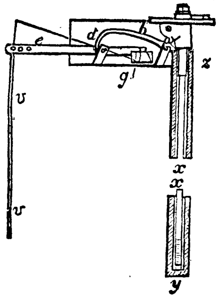

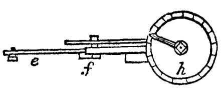

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a, *b*, *d*; thence the slightest increase of heat lengthens the tube anew and the collet lifting the heel of the lever, depresses the other end *d* through a much greater space, on account of the relative lengths of its legs. This movement operates near the axis of a balance-bar *e*, sinks one end of this, and thereby increases the extent of the movement which is transmitted directly to the iron skewer *v*. This pushing down a swing register diminishes or cuts off the access of air to the fire-place. The combustion is thereby obstructed, and the temperature falling by degrees, the tube shrinks and disengages the heel of the lever. The counterpoise *g*, fixed at the balance-beam *e*, raises the other extremity of this beam by raising the end *d* of the lever as much as is necessary to make the heel bear upon the collet of the tube. The swing register acted upon by this means, presents a greater section to the passage of the air; whence the combustion is increased. To counterbalance the effect of atmospheric changes, the iron stem which supports the regulator is terminated by a dial disc, round the shaft of the needle above *h*, *fig.* 759.; on turning this needle, the stem below it turns, as well as a screw at its under end, which raises or lowers the leaden tube. In the first case, the heel falls, and opens the swing register, whence a higher temperature is required to shut it, by the expansion of the tube. We may thus obtain a regularly higher temperature. If, on the contrary, we raise the tube by turning the needle in the other direction, the register presents a smaller opening, and shuts at a lower temperature; in this case, we obtain a regularly lower temperature. It is therefore easy, says M. Bonnemain, to determine *à priori* the degree of temperature to be given to the water circulating in the stove pipes. In order to facilitate the regulation of the apparatus, he graduated the disc dial, and inscribed upon its top and bottom, the words, Strong and Weak heat. See THERMOSTAT, for another HEAT-REGULATOR.

HEAVY-SPAR, *sulphate of Baryta, or Cawk;* (*Spath pesant*, Fr.; *Schwerspath*, Germ.) is an abundant mineral, which accompanies veins of lead, silver, mercury, &c., but is often found, also, in large masses. Its colour is usually white, or flesh coloured. It occurs in many crystalline forms, of which the cleavage is a right rhomboidal prism. It is met with also of a fibrous, radiated, and granular structure. Its spec. grav. varies from 4·1 to 4·6. It has a strong lustre, between the fatty and the vitreous. It melts at 35° Wedgw. into a white opaque enamel. Its constituents are 65·63 baryta, and 34·37 sulphuric acid. It is decomposed by calcination in contact with charcoal at a white heat, into a sulphuret of baryta; from which all the baryta salts may be readily formed. Its chief employment in commerce is for adulterating white lead; a purpose which it readily serves on account of its density. Its presence here is easily detected by dilute nitric acid, which dissolves the carbonate of lead, and leaves the heavy spar. It is also a useful ingredient in some kinds of pottery, and glass.

HECKLE; (*Seran*, Fr.; *Hechel*, Germ.) is an implement for dissevering the filaments of flax, and laying them in parallel stricks or tresses. See FLAX.

HELIOGRAPHY may be regarded as the appropriate title of the new and elegant art of making *sun pictures*; an art which originated with Niepce and Daguerre, and which has been much improved by Mr. Fox Talbot. See the articles CALOTYPE and DAGUERREOTYPE. It has been called photography, being a picture produced by the action of light; but as the sunbeams are essential to a good result, I have called it *Heliography.*

Iodide of silver is the principal agent applied to paper, to make it very sensible to the impressions of the sunbeam. The bromide has also been used, and preferably in mixture. Le Gray in his new treatise of photography, lately published, recommends a mixture of the Iodide, cyanide and fluoride, as the excitable fluid; this compound being used in union with potassium. The paper thus impregnated, is laid on the aceto-nitrate of silver, and then exposed to the light. A picture may thus be obtained in the focus of the camera obscura in 30 seconds in fine weather; a circumstance of great consequence in taking living portraits, on account of the mobility of the human countenance. Waxed paper applied dry possesses a like sensibility.

One of the main difficulties in heliography lies in the choice of the paper. The post paper of Whatman of London, is preferred for the preliminary trials, when it is slightly glazed. Thin paper is better for portraiture, and thick for landscapes. Well sized paper is to be preferred, and of equal texture.

The first step in preparing the paper, is to fill up all its pores with fine white-wax and thus give it the aspect of parchment. Provide a large plate of silver-plated, as for the daguerreotype process, place it on a tripod horizontally, heat it by passing the flame of a spirit of wine lamp to and fro under it, or rather set it over a water bath, while with the other hand a piece of white wax is rubbed over it. The coat of wax being equally fused, lay the paper upon it, and cause it to apply evenly by putting a card on it. It is then to be removed, and laid between two or three folds of blotting paper, and gently pressed over with a hot smoothing iron, to remove the excess of wax. It is indispensable that no wax remain on the surface, but only in the texture of the paper; which should have no glistening spot, and be perfectly transparent. Thin paper should be preferred for waxing. Well prepared paper should allow the proof of the picture to develop itself in the gallic acid for a considerable time, without spotting either the proof or the acid. Its principal quality is, to permit the aceto-nitrate of silver to be prepared beforehand, and thus have a store of ready waxed paper. This preparation affords very intense blacks upon thin papers.

The bath of iodide of potassium completely penetrates the wax, and deprives it of its greasy aspect, by a sort of decomposition, which causes the subsequent preparations to apply uniformly. This paper should be left from half an hour to an hour, in the solution of the iodide, according to the thickness of the paper; to ensure the decomposition of the wax, care must be taken to keep the waxed paper cool. The iodized paper assumes a violet tint when completely dry. This hue, resulting from the union of the wax with the iodine, is beneficial, because it affords sufficient time to leave the paper on the aceto-nitrate of silver, till the violet tint disappears. The preparations that follow may be applied to either the waxed or plain paper; but in the latter case, the paper should be somewhat thick.

First Preparation.—Negative Paper.—Boil in a porcelain or earthen pan, 3 litres of distilled water, with 250 grammes of rice, till this merely bursts, lest the water becomes too glutinous. Strain through calico. This forms an excellent size, and affords a good body and fine blacks. In a litre of the above rice water, dissolve 40 grammes of sugar of milk; 15 of iodide of potassium; 80 centigrammes of cyanide of potassium, and 50 centigrammes of fluoride of potassium. Filter the solution, and set aside for use in a bottle. To prepare the paper, pour this solution into a large plate, and plunge the waxed paper into it, leaf by leaf over each other, taking care to expel the air bubbles. Take them out, return them for about half an hour; then hang them up to dry, by means of a bent pin hooked to the corner; and favour their drainage by placing a bit of blotting paper on their lower point. This process is to be repeated. French and English papers should not be mixed in the same cistern. The English paper is said to contain a free acid, which precipitates iodide of starch in the French paper, and gives it a deep violet tint. The paper is to be cut down to the size of the camera obscura, and put up for use in a porte-feuille. The liquid which has been used will serve again. The paper thus prepared, is called iodized.

Paper spceially for Portraiture—is prepared as follows. Take 400 grammes of distilled water, 20 of iodide of potassium, 2 of cyanide of potassium, 0·50 centigrammes of fluoride of potassium;—dissolve. Pour 2 or 3 millimetres of this solution into a flat plate of porcelain, or on a flat glass, quite horizontal. Take a piece of glazed paper by the two corners, the rough side uppermost, and apply the smooth face upon the liquid in the plate; beginning the immersion with the side next your body, and pushing the leaf before you, so that it may always fall at right angles upon the liquid. This movement is to be repeated two or three times, so as to press out any air bubbles. Take care that the liquid does not pass to the other side of the paper. It is to remain on the bath not more than two minutes at most. It is then to be lifted and perfectly dried between folds of blotting paper, of a fine tissue, rubbing it in all directions with the hands, and changing its place, that it may be perfectly dry. Remove the paper and smooth it with a soft brush. Lay the same side upon the bath of aceto-nitrate of silver (about to be indicated); leaving it there not more than 8 or 10 seconds at most, and then place it upon the slate in the camera, (which has been previously furnished with a leaf of blotting paper well soaked in water, as will be described further on. It is requisite to make immediate use of this paper, because its great sensibility depends chiefly on the nascent state of the iodide of silver that it operates upon. In summer, from 4 to 10 seconds are required for an impression; in winter, from 18 to 40.

The second operation is to give sensibility to the iodized papers, either in the dry or humid way. Take of

Distilled water - - - - -	150 grammes
Crystallized nitrate of silver - -	5 "

When this is dissolved, add of crystallizable acetic acid 12 grammes. Care must be taken to prepare this solution by the light of a feeble taper, and to surround the phial with a case of blackened paper. No more of this mixture should be put into the capsule than is sufficient for once. If not to be kept more than 4 days upon the paper, the following mixture may be used:

Distilled water	150	grammes
Acetate of silver	10	"
Crystallizable acetic acid	12	"

For the humid operation the paper may preferably be employed moist. At the moment of commencing, pour one of those mixtures of aceto-nitrate of silver upon a plate of porcelain or glass, quite horizontal, to about one millimetre in depth. A pipette or small sucking glass tube is convenient for this purpose, as its fine point prevents any drops from being spilled irregularly. And the surface of the liquid may be skimmed if necessary with a piece of white paper. The leaf of iodized paper is now to be seized by the two corners on the side only which was iodized, and to be laid down and raised several times so as to expel the air. This may be done with the thumb by the help of a pallet ivory knife to save staining the fingers. Take care that none of the nitro-acetate of silver goes on the other side of the paper. Allow the paper to receive the chemical action till the formation of a very sensible layer of cyano-iodo-fluoride of silver. Five minutes may suffice for the French paper, and a little longer for the English; both being imbued with the sugar of milk preparations. Time should be given for the violet hue to disappear,—4 or 5 minutes; but with the portrait paper, 9 or 10 seconds should be sufficient. The longer this interval the less is the sensibility.

Apply the paper quite moist upon a slate, on which there has been previously spread to receive it, a well soaked leaf of unsized paper. The sole of the camera may also be made use of, if it has been well covered with a coat of white wax. But the slate is preferable; care being had to lay the surface with the aceto-nitrate uppermost to receive the radiations of light. The undermost piece of paper should be free from iron stains. The slate should be marked so as to be preserved always in one posture, both when they are applied and when put up in the frame. If these precautions be neglected, the liquid collects below and falls upon the prepared paper, and may cause spots. The paper, when thus put on the slate, may be left there for three or four hours without being removed, and may be placed during this interval in the camera. On going a little way off to take a proof, the fold of the leaf may be dipped in thick mucilage of gum-arabic, which serves to preserve the moisture and the adhesion. Two panes of glass may also be used for laying the papers between; not sparing blotting paper in cleaning them.

In the dry way, waxed paper is to be used. It will require more time to develop the image with the gallic acid; but this comes out equally well, only there will be a pretty strong contrast between the whites and the blacks. The aceto-gallic acid, and the aceto-nitric, which are added should be fresh, extremely pure, and well filtered. Two porcelain basins of some depth are to be taken; into the first put from 5 to 6 millimetres of aceto-nitric acid (noted above) and into the second put distilled water. Plunge completely on the two sides the waxed and iodized paper, into the bath of the aceto-nitrate of silver of the first cistern, and leave it there 4 or 5 minutes, then transfer it immediately into the bath of distilled water in the second cistern, and leave it at least 4 minutes or more if you wish to keep the paper some time before using it. You may prepare next in the same baths, ten leaves one after the other. Lastly, the paper is to be taken from the water to be dried between folds of blotting paper, and laid by in a blotting-book equally dry. The paper is not to be dried by suspension in the air. Kept in the dark the paper will thus keep its qualities fully 5 days, before going into the camera. The aceto-nitrate of silver deteriorates after 8 days. It is good not to put at once more than one or two proofs into the same bath of gallic acid. The period of exposure in the camera is not longer in the dry than in the humid way, but the proof must stand a little longer in the gallic acid, which may have 15 or 20 drops added to it of the nitro-acetate of silver filtered, and fresh made, or not previously used. The granular and soiled look of the paper under the gallic acid when it becomes dry, should give no concern, as it disappears completely on re-melting the wax, of the proof on the exposure of its negative to a suitable heat. This precaution should never be neglected, for it is superior to any varnish. These operations being finished, invert the aceto-nitrate of silver into a phial, but don't reserve any for fresh proofs, which would prove a constant cause of failures. It may be thrown down by common salt, in the state of chloride of silver, which serves to give to hyposulphite of soda, the quality necessary for producing fine tones. The aceto-nitrate may be decoloured and revived by means of bone black, with which it is to be boiled a short time and then filtered.

Third Operation: Exposure in the Camera.—Place the point of the image in the depolished glass most scrupulously in the middle of the lens. After the exposure to the luminous rays the image in the camera has little appearance, being developed only by

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the subsequent operation, which may be performed some hours afterwards, on the moist paper, or even some days with the waxed paper in the dry state.

Development of the Image.—This is effected by the gallic acid diluted with pure water, in the proportion of 1 litre of the latter and 4 grammes of the former. Pour out of this solution into a horizontal flat shallow plate, to the thickness of 3 or 4 millimetres. Plunge the proof completely into it, so that it may be covered all round. Watch its development, which is readily perceived across the thickness of the paper. It may be left here from 10 minutes for an hour or two, till it be arrived at perfection. The development is much quickened by adding 20 or 21 drops of aceto-nitrate of silver, when the image begins to appear. Very intense blacks are thus obtained, but the action must then be followed up, because it is rapid, and it gives such intense blacks, as to be disagreeable if the time be prolonged. When it is sufficiently deep, withdraw it smartly, and pour several streams of water over it, upon a plate or dish, rubbing the back of the paper at the same time with a finger to remove any crystalline grains which might spoil it. The gray hue of the waxed paper need cause no alarm as it disappears, and leaves beautiful whites and blacks. The tone which the image takes from the gallic acid will enable you to judge whether the exposure to the light has been adequate. If it becomes immediately of a gray black everywhere (looked well through), it shows it to have been too long under the light. If the greatest lights, which should be the greatest blacks of the negative, do not become deeper than the semi-tints, the exposure has also been too long. A first proof serves to regulate the time of exposure in the camera for the rest. Its period may be shortened by warming the gallic acid, for which a little apparatus has been used, consisting of a little square copper basin filled with water, supported over a small spirit lamp, which communicates heat to the shallow dish containing the gallic acid, &c.

The picture taken as above described will not be permanent. It must be fixed by the

Fifth Operation, or that of the Negative Proof.—Dissolve in a bottle 100 grammes of hyposulphite of soda in 800 grammes of filtered water. Put the solution into a basin to the depth of half a centimetre, and plunge the negative proof completely in it, taking care to free it from air bubbles. The hyposulphite takes possession of the cyano-iodo-fluoride of silver, and the proof remains clear; but it does not affect the gallate of silver, which on the contrary continues black. Never put more than one proof at a time in this bath; but you may put several proofs in it one after the other. The hyposulphite of soda which has been already used is to be collected, and when kept, lets fall flocks of gallate of iron and sulphuret of silver. When filtered it serves well for fixing weak proofs. On examining the proof after it has remained some time in the bath, we might be tempted to believe that it has lost its strength from its transparency, because the iodide of silver, which has a straw yellow tint, being completely removed from its place and resting at other spots, annihilates the image in appearance. But if we consider that the whole iodide of silver is removed, as is recognized when the yellow tint of the proof is also gone—one becomes astonished at the whiteness and the transparency of the paper; as well as the beauty of the blacks of the image.

For these effects it requires from half an hour to three quarters of an hour with the ordinary papers. An abode of too much length in the bath weakens the blocks of the proof; and, therefore, this process should be looked after. With waxed papers, from 10 to 15 minutes are sufficient for fixing. The proof is to be next washed with several waters, and left to drain off its hyposulphite into a basin for the space of half an hour. It is then dried by hanging it up by a corner; and is now inalterable at the light, since there does not remain any more in the paper than the black gallate of iron.

Sixth Operation: Waxing of the Negative Proof.—When the negative proof is weak and the paper very transparent, counterproofs should be made with it without waxing. The proofs obtained from paper previously waxed should not be waxed anew, but only approached near the fire to restore their transparency, which they had lost by their successive baths. Before this operation they have a granular aspect. The negative proof should be waxed, which counteracts the ill effect of any of the nitrate of silver remaining on the surface of the positive paper. The waxing of the negative proof is done by melting with a spirit lamp a layer of white wax on a piece of plated copper like that of a daguerreotype, laying the negative upon it, and promoting its adhesion by the weight of a card. When it is equally soaked, place it between folds of smooth writing paper, and glide a hot smoothing iron over all to remove the excess of wax. The iron should not be too hot.

Seventh Preparation; that of Positive Paper.—Saturate a bottle of water with sea salt. Dilute 1 part of this solution with 3 parts of water. Put into a plate this brine to the depth of 4 or 5 millimetres. Into another bottle put of distilled water 100 grammes; crystallized nitrate of silver 20 grammes. Dissolve. Of which pour out into a plate to the above thickness.

Take stout paper weighing about 15 kilogrammes the ream, previously cut of a suitable size, and free from iron stains or any impurities. Mark a cross on the side of the paper which bears the metallic mark of the manufacturer. Le Gray says the English paper should not be used unless a red tone be wanted in the pictures. Place the paper upon a plate of porcelain or glass moistened (as formerly directed) with the dilute brine, and leave it there from 2 to 4 minutes; dry it between folds of pink blotting paper, rubbing it at the same time with the hand. Prepare thus 3 leaves before beginning, to put them in the bath of nitrate of silver, in order that all traces of humidity may be removed. Take the dried leaves and clear them by a somewhat hard flat brush from all particles of salt or other impurities. Put a leaf of the pink blotting paper upon the nitrate of silver of the salted side only, and leave it there the time requisite to prepare another leaf upon the salt. By leaving it for a little on the nitrate of silver, red tones are obtained; but, by leaving it longer, blacker tones. The paper is then to be dried, hanging it up by a corner; but all must be done by candlelight. The positive paper should be very dry before laying a negative upon it, for fear of staining it with nitrate of silver. On this account it is good to dry it well the previous night, but not too many days beforehand, lest the silver should darken.

Eighth Operation: Taking the Positive Proof.—Put the negative upon one of the glasses of the frame of reproduction, lay above it a leaf of glazed paper, then one of positive paper prepared by the preceding operation, the side of the preparation upon the place of the negative, then lay above it a leaf of black paper, and the second glass of the frame. Shut the cover of the frame, which will exert a slight pressure upon the glasses, and secure their contact. A sheet of transparent and waxed paper, or a piece of *papier glaçé in gelatine*, should be placed between the negative proof and the leaf of the positive paper. This does not hurt the nicety of the proof, and preserves the negative from contact with the nitrate of silver,. which would spoil it. It is proper to allow one of the sides of the positive paper to overlap on the side of the negative, in order to judge of the action of the light. Expose the frame to the solar or diffuse light, so that the rays fall vertically upon the surface of the proof. Trace the progress of the proof by the tone of the folded over-part of the paper, as per the following gradations of tint: Gray blue, neutral tint, violet blue, black blue, black, bistre, coloured sepia, yellowish sepia, dead leaf colour, greenish-gray; always wearing away, till the oxide of silver be at last reduced to the state of a metallic oxide. It is proper to stop at some one of these tones, accord-to the greater or less vigour of the negative, and the depth of the proof that is desired. Once we have obtained a proof with a negative, we may be sure when we stop at the same tint of the overlapping edge, we shall have the same result. To have a proof of a black tint, for example, after the fixing of the hyposulphite, the deep parts should have the tone of sepia, and the parts which should form the whites, have a blue-gray, on withdrawing it from beneath the frame, in order to repair the loss of tone given by the hyposulphite. The precise time of the exposure to the light cannot, therefore, be fixed, and is subordinate to the intensity both of the negative, and also of the proof which is desired.

Ninth and last Operation: Fixing of the Positive Proof.—This proof would not be permanent without being immediately fixed by the following process:

Dissolve in a bottle 100 grammes of hyposulphite of soda, with 600 of filtered water; and in another bottle dissolve 5 grammes of nitrate of silver in a couple of glasses of water, and add a solution of common salt, till no more white precipitate falls. After letting it settle to the bottom of the vessel, collect the chloride of silver in a piece of calico, and put it into the preceding solution of the hyposulphite. Thus, black tones may be obtained with this new hyposulphite. The older this hyposulphite is the better. When it becomes turbid, a little more fresh solution need only be added to it. We must also beware of filtering it to remove the black deposit which is formed; we have only to let it remain at rest in a large bottle, and decant the clear liquor for use, so as not to lose the black deposit, and to redissolve it by means of fresh hyposulphite. By means of a stay shorter or longer in this bath, almost all the tones may be obtained from the red to the black, and the pale yellow; so that, with a little practice, any desired tint may be secured. The proof should be left in the bath at least an hour to be sufficiently fixed; and it may remain in it from 3 to 4 hours to bring out the sepia and the yellow tones. By heating the hyposulphite, we may quicken the operation, but we must not leave the proof an instant to itself, because the action is rapid, and the picture might become effaced. In this case it is good to add a little acetic acid to the hyposulphite, in order to preserve the whites.

On adding to the preceding solution of the hyposulphite 25 grammes of ammonia, very pretty bistre tones are obtained along with very pure whites. English paper suits these effects very well. Very fine velvety tones are obtained by putting the proof (on taking out of the hyposulphite) upon a bath of salt of gold (1 gramme of the salt into a litre of water), sharpened with 5 grammes of nitro-muriatic acid.

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Very fine yellow tones have been obtained by putting a proof pretty strong at first into the hyposulphite, then into a bath composed of a litre of water, and 50 grammes of hydrochloric acid; finally rinsing it with water. Water of ammonia used in the same dose, without putting the proof previously in the hyposulphite of soda, gives also remarkable tones. When the proof is of the desired tone, wash it with several waters, and leave it two or three hours in a basin, taking it out only when the proof has no longer a sweet taste on the tongue, characteristic of the hyposulphite of silver. It is to be then dried by hanging by a corner; when it is finished. The hyposulphite bath may contain as many proofs as we please at a time. But great care must be taken to entangle no air bubbles among the leaves, which would produce indelible black spots. A long-haired pencil is useful for clearing away these bubbles. The taking of the positive proofs requires all the attention of a skilful operator, and it must not be disregarded. It is necessary to calculate rightly the shade of a proof with the subject, and the effect wished to be produced.. A superior fine proof should be put by itself in the hyposulphite of soda.

Heliographs or Photographs have been recently taken of extreme accuracy and fineness of delineation, upon glass coated with albumen, by the following recipe:—Put the whites of ten eggs into a large basin; dissolve in them, by beating them with a box-wood fork, 4 grammes of iodide of potassium; ½ gramme of bromide of ammonia, and as much chloride of sodium. Reduce it to a white thick froth, leave it to settle for a night, and next morning decant the viscid liquor which has fallen, and keep it for use. This glairy compound is best when applied to depolished glass. A film of collodium on glass is now preferred. For the remaining minute precautions and directions, I refer to the publication of M. Le Grey, entitled *Nouveau Traitė Thėorique et Pratique de Photographie.*

HELIOTROPE; is a variety of jasper, mixed with chlorite, green earth, and diallage; occasionally marked with blood-red points; whence its vulgar name of *blood-stone.*

HEMATINE; is the name given by its discoverer Chevreul to a crystalline substance, of a pale pink colour, and brilliant lustre when viewed in a lens, which he extracted from logwood, the *hæmatoxylon Campechianum* of botanists. It is, in fact, the characteristic principle of this dye-wood. To procure hematine, digest during a few hours ground logwood in water heated to a temperature of about 130° Fahr.; filter the liquor, evaporate it to dryness by a steam bath, and put the extract in alcohol of 0·835 for a day. Then filter anew, and after having inspissated the alcoholic solution by evaporation, pour into it a little water, evaporate gently again, and then leave it to itself in a cool place. In this way a considerable quantity of crystals of hematine will be obtained, which may be readily purified by washing with alcohol and drying.

When subjected to dry distillation in a retort, hematine affords all the usual products of vegetable bodies, along with a little ammonia; which proves the presence of azote. Boiling water dissolves it abundantly, and assumes an orange-red colour, which passes into yellow by cooling, but becomes red again with heat. Sulphurous acid destroys the colour of solution of hematine. Potash and ammonia convert into a dark purple-red tint, the pale solution of hematine; when these alkalis are added in large quantity, they make the colour, violet blue, then brown-red, and lastly brown-yellow. By this time the hematine has become decomposed, and cannot be restored to its pristine state by neutralizing the alkalis with acids.

The waters of baryta, strontia, and lime exercise an analogous power of decomposition; but they eventually precipitate the changed colouring matter.

A red solution of hematine subjected to a current of sulphuretted hydrogen becomes yellow; but it resumes its original hue when the sulphuretted hydrogen is removed by a little potash.

The protoxide of lead, the protoxide of tin, the hydrate of peroxide of iron, the hydrate of oxides of copper and nickel, oxide of bismuth, combine with hematine, and colour it blue with more or less of a violet cast.

Hematine precipitates glue from its solution in reddish flocks. This substance has not hitherto been employed in its pure state; but as it constitutes the active principle of logwood, it enters as an ingredient into all the colours made with that dye stuff.

These colours are principally violet and black. Chevreul has proposed hematine as an excellent test of acidity.

HÉMATITE; (*Fer Oligiste*, Fr.; *Rotheisenstein*, Germ.) is a native reddish-brown peroxide of iron, consisting of oxygen 30·66; iron 60·34. It is the kidney ore of Cumberland which is smelted at Ulverstone with charcoal, into excellent steel iron.

HEMP; (*Chanvre*, Fr.; *Hanf*, Germ.) is the fibrous rind of the bark of the *cannabis sativa*, which is spun into strands or yarn for making rope, sail-cloth, &c. It is prepared for spinning in the same way as flax, which see. *Hemp-seed* contains an oil which is employed for making soft soap, for painting, and for burning in lamps. See OILS.

The importation of undressed hemp for home consumption in 1851 and 1852, was respectively 1,048,635 cwts. and 1,293,412 cwts.

HEPAR; which signifies liver in Latin, was a name given by the older chemists to some of those compounds of sulphur with the metals which had a liver-brown colour Thus the sulphuret of potassium was called liver of sulphur.

HEPATIC AIR; sulphuretted hydrogen gas.

HERMETICAL SEAL, is an expression derived from Hermes, the fabulous parent of Egyptian chemistry, to designate the perfect closure of a hollow vessel, by the cementing or melting of the lips of its orifice; as in the case of a glass thermometer, or matrass.

HIDE; (*Peau*, Fr.; *Haut*, Germ.) the strong skin of an ox, horse, or other large animal. See Leather.

		Imports.		Exports.	
		1851.	1852.	1851.	1852.
Untanned, dry - -	cwts.	150,575	187,091	83,799	113,727
wet - -	cwts.	441,346	485,076	29,779	43,200
Tanned, tawed, curried or dressed (except Russia hides) - - -	lbs.	1,876,557	2,275,107	105,924	79,817

HIRCINE; from *hircus*, a ram; is the name given by Chevreul to a liquid fatty substance, which is mixed with the oleine of mutton suet, and gives it its peculiar rank smell. Hircine is much more soluble in alcohol than oleine. It produces *hircic* acid by saponification.

HOG'S LARD; see Fats.

HOLLOW FOUNDING. Candlesticks are cast in sand and made hollow, by the introduction into the mould of what is called a "core," viz., a piece of sand corresponding in size to the hollow of the pillar. Upon his skill in making this in such a manner as to produce uniform thickness of metal throughout, depends the success of the workman; the metal must also be of a proper temperature, or the casting is rendered useless by the presence of flaws. Candlesticks are finished by being turned and polished by friction, when in a state of motion in the lathe; the bottoms, when round, are also turned; when square, they are filed and polished. The composition of metal in this case is copper and zinc, in the proportion of 10 ounces of the former to 8 ounces of the latter.

HOMBOURG; MINERAL WATERS OF. The city of Hombourg near Frankfort, is situated at the bottom and to the east of the mountains of Taunus, 600 ft. above the level of the sea, in a picturesque position.

The Elizabeth spring consists by Liebig's analysis in 16 ozs. of—

	Grains.
Chlor. sodium - - - - - -	79·1547
Sulphate of soda - - - - - -	0·3809
Chlor. calcium - - - - - -	7·7568
Chlor. magnesium - - - - - -	7·7670
Silica - - - - - - -	0·3157
Carbonate of lime - - - - -	10·9824
Do. of magnesia - - - - -	2·0111
Proto-carbonate of iron - - - - - -	0·4608
Free carbonic acid. - - - - - -	21·4808
	130·3102

THE BATH SPRING. Contains for 16 oz. of water, 22·728 cubic in. of carbonic acid combined with—

	Grains.
Sulphate of lime - - - - - -	0·212
Chlor. calcium - - - - - -	15·285
Brom. magnesium - - - - - -	0·002
Chlor. do. - - - - - -	5·904
Chlor. potassium - - - - - -	0·384
Do. sodium - - - - - -	108·392
Silica - - - - - - -	0·164
Proto-carbonate of iron - - - - - -	0·480
Alumina - - - - - - -	0·054
Carbonate of lime - - - - - -	9·698
Do. magnesia - - - - - -	2·485
	143.060

To this water are added occasionally some of the salt springs of Bingen, which contain considerable quantities of the compounds of bromine and iodine.

Mother Water, is the name given to the clear liquor which remains in the boiler, when, after evaporating the water, the common salt has been crystallized and separated. This residuum is greasy to the touch, but a little thinner than oil, and when applied to the skin covers it with small scales, as if it had been washed with chlor-calcium. Iodine and bromine exist in it, and are supposed to give it efficacy against scrofulous and chronic diseases.

HONEY; (*Mel*, Fr.; *Honig*, Germ.) is a sweet viscid liquor, elaborated by bees from the sweet juices of the nectaries of flowers, and deposited by them in the waxen cells of their combs. Virgin honey is that which spontaneously flows with a very gentle heat from the comb, and common honey is that which is procured by the joint agency of pressure and heat. The former is whitish or pale yellow, of a granular texture, a fragrant smell, and a sweet slightly pungent taste; the latter is darker coloured, thicker, and not so agreeable either in taste or smell. Honey would seem to be simply collected by the bees, for it consists of merely the vegetable products; such as the sugars of grape, gum, and manna; along with mucilage, extractive matter, a little wax and acid.

HONEY-STONE; (*Mellite*, Fr.; *Honigstein*, Germ.) is a mineral of a yellowish or reddish colour, and a resinous aspect, crystallizing in octahedrons with a square base; specific gravity 1·58. It is harder than gypsum, but not so hard as calc-spar; it is deeply scratched by a steel point; very brittle; affords water by calcination; blackens, then burns at the flame of the blowpipe, and leaves a white residuum which becomes blue, when it is calcined after having been moistened with a drop of nitrate of cobalt. It is a mellate of alumina, and consists of:

	Klaproth.	Wöhler.
Mellitic acid - - - - - - - - -	46	44·4
Alumina - - - - - - - - -	16	14·5
Water - - - - - - - - -	81	41·1
	100	100·0

The honey-stone, like amber, belongs to the geological formation of lignite. It has been hitherto found clearly in only one locality, at Artern in Thuringia.

HOP; (*Houblon*, Fr.; *Hopfen*, Germ.) is the name of a well-known plant of the natural family of Urticeæ, and of the diœcia pentandria of Linnæus. The female flowers, placed upon different plants from the male, grow in ovoid cones formed of oval leafy scales, concave, imbricated, containing each at the base an ovary furnished with two tubular open styles, and sharp pointed stigmata. The fruit of the hop is a small rounded seed, slightly compressed, brownish coloured, enveloped in a scaly calyx, thin but solid, which contains, spread at its base, a granular yellow substance, appearing to the eye like a fine dust, but in the microscope they seem to be round, yellow, transparent, grains; deeper coloured, the older the fruit. This secretion, which constitutes the useful portion of the hop, has been examined in succession by Ives, Planche, Payen, and Chevallier. I have given a pretty full account of the results of their researches in treating of the hop under the article Beer.

Annual Amount of Hop Duty, Average Price per Cwt., and Number of Acres.

Year.	Duty.	Average Price.	No. of Acres.
	£	£ s. d.	
1838	171,556	5 17 0	55,045
1839	205,537	4 10 0	52,305
1840	34,091	13 11 0	44,805
1841	146,159	6 6 0	45,769
1842	169,773	4 18 0	43,720
1843	133,508	8 0 0	43,156
1844	140,322	7 15 0	44,485
1845	158,003	7 10 0	48,058

Pounds Weight of Hops which paid Duty from 1840 to 1845

	Lbs.
1840	7,114,917
1841	30,504,106
1842	35,432,142
1843	27,862,725
1844	29,285,092
1845	32,974,749

Number of Acres under the Cultivation of Hops in England.

1807	38,218	1813	39,521	1819	51,014	1825	46,718	1831	47,129	1837	56,323
1808	38,436	1814	40,571	1820	50,148	1826	50,471	1832	47,101	1838	55,045
1809	38,357	1815	42,150	1821	45,662	1827	49,485	1833	46,187	1839	52,305
1810	38,265	1816	44,219	1822	43,766	1828	48,365	1834	51,273	1840	44,805
1811	38,401	1817	46,493	1823	41,458	1829	46,135	1835	53,816	1841	45,769
1812	38,700	1818	48,593	1824	43,449	1830	46,726	1836	55,422	1842	

Annual amount of hop duty.

Yrs.	Amount.	Yrs.	Amount.	Yrs.	Amount.	Yrs.	Amount.	Yrs.	Amount.	Yrs.	Amount.
1711	£43,437	1733	£70,215	1755	£82,157	1777	£43,581	1799	£73,279	1821	£154,609
1712	30,278	1734	37,716	1756	48,106	1778	159,891	1800	72,928	1822	203,724
1713	23,018	1735	42,745	1757	69,713	1779	55,800	1801	241,227	1823	26,058
1714	14,457	1736	46,482	1758	72,896	1780	122,724	1802	15,463	1824	148,832
1715	44,975	1737	56,492	1759	42,115	1781	120,218	1803	199,305	1825	24,317
1716	20,354	1738	86,575	1760	117,992	1782	14,895	1804	177,617	1826	269,331
1717	54,669	1739	70,742	1761	79,776	1783	75,716	1805	32,904	1827	140.848
1718	15,005	1740	37,875	1762	79,295	1784	94,359	1806	153,102	1828	172,027
1719	90,317	1741	65,222	1763	88,315	1785	112,684	1807	100,071	1829	38,398
1720	38,169	1742	45,550	1764	17,178	1786	95,973	1808	251,089	1830	88,047
1721	61,362	1743	61,072	1765	73,778	1787	42,227	1809	63,452	1831	174,864
1722	49,443	1744	46,708	1766	116,445	1788	143,168	1810	73,514	1832	139,018
1723	30,279	1745	34,635	1767	25,997	1789	104,063	1811	157,025	1833	156,905
1724	61,271	1746	91,879	1768	114,002	1790	106,841	1812	30,633	1834	189,713
1725	6,526	1747	62,993	1769	16,201	1791	90,059	1813	131,482	1835	235,207
1726	80,031	1748	87,155	1770	101,131	1792	162,112	1814	140,202	1836	200,332
1727	69,409	1749	36,805	1771	33,143	1793	22,619	1815	123,878	1837	178,578
1728	41,494	1750	72,138	1772	102,650	1794	203,063	1816	46,302	1838	171,556
1729	48,441	1751	73,954	1773	45,847	1795	82,342	1817	66,522	1839	205,537
1730	44,419	1752	82,163	1774	138,887	1796	75,223	1818	199,465	1840	34,091
1731	22,600	1753	91,214	1775	41,597	1797	157,458	1819	242,476	1841	146,159
1732	35,135	1754	102,012	1776	125,691	1798	56,032	1820	138,330	1842	169,776

Hop duties of particular districts.

	1839.	1840.	1841.	1842.
Rochester - - -	£60,802 16 6	£23,256 19 8	£51,490 3 8	£58,812 4 7
Canterbury - -	50,649 3 0	5,757 0 4	33,960 14 10	31,019 13 5
Kent - - - - -	111,451 19 6	29,014 0 0	85,450 18 6	90,731 18 0
Sussex - - -	65,026 19 7	3,080 12 9	38,086 13 10	43,561 10 0
Worcester - - -	16,639 16 4	239 19 0	12,076 19 8	19,815 2 11
Farnham - - -	7,730 7 2	1,643 18 7	7,702 10 2	11,678 18 4
North Clays - - -	2,005 13 10	57 4 1	1,159 7 10	1,724 2 7
Essex - - - -	1,624 5 9	35 17 1	977 3 0	2,050 19 11
Sundries - - -	1,058 11 5	20 4 8	705 8 7	203 14 3
	205,538 12 7	34,091 17 2	146,159 1 7	169,776 6 0

HORDEINE is the name given by Proust to the peculiar starchy matter of barley. It seems to be a mixture of the starch, lignine, and husks, which constitutes barley meal. See Beer.

HORN (Eng. and Germ.; *Corne*, Fr.), particularly of oxen, cows, goats, and sheep, is a substance soft, tough, semi-transparent, and susceptible of being cut and pressed into a variety of forms; it is this property that distinguishes it from bone. Turtle or tortoise shell seems to be of a nature similar to horn, but instead of being of a uniform color, it is variegated with spots.

These valuable properties render horn susceptible of being employed in a variety of works fit for the turner, snuff-box, and comb maker. The means of softening the horn need not be described, as it is well known to be by heat; but those of cutting, polishing, and soldering it, so as to make the plates of large dimensions, suitable to form a variety of articles, may be detailed. The kind of horn to be preferred is that of goats and sheep, from its being whiter and more transparent than the horn of any other animals. When horn is wanted in sheets or plates, it must be steeped in water, in order to separate the pith from the kernel, for about fifteen days in summer, and a month in winter; and after it is soaked, it must be taken out by one end, well shaken and rubbed, in order to get off the pith; after which it must be put for half an hour into boiling water, then taken out, and the surface sawed even, lengthways; it must again be put into the boiling water to soften it, so as to render it caqable of separating; then, with the help of a small iron chisel, it can be divided into sheets or leaves. The thick pieces will form three leaves, those which are thin will form only two, whilst young horn, which is only one quarter of an inch thick, will form only one. These plates or leaves must again be put into boiling water, and when they are sufficiently soft, they must be scraped with a sharp cutting instrument, to render those parts that are thick even and uniform; they must be put once more into the boiling water, and finally carried to the press.

At the bottom of the press employed, there must be a strong block, in which is formed a cavity, of nine inches square and of a proportionate depth; the sheets of horn are to be laid within this cavity, in the following manner at the bottom: first a sheet of hot iron, upon this a sheet of horn, next again a sheet of hot iron, and so on, taking care to place at the top a plate of iron even with the last. The press must then be screwed down tight.

There is a more expeditious process, at least in part, for reducing the horn into sheets, when it is wanted very even. After having sawed it with a very fine and sharp saw, the pieces must be put into a copper made on purpose, and there boiled, until sufficiently soft, so as to be able to split with pincers; the sheets of horn must then be put in the press, where they are to be placed in a strong vice, the chaps of which are of iron and larger than the sheets of horn, and the vice must be screwed as quick and tight as possible; let them cool in the press or vice, or it is as well to plunge the whole into cold water. The last mode is preferable, because the horn does not shrink in cooling. Now draw out the leaves of horn, and introduce other horn to undergo the same process. The horn so enlarged in pressing, is to be submitted to the action of the saw, which ought to be set in an iron frame, if the horn is wanted to be cut with advantage, in sheets of any desired thickness, which cannot be done without adopting this mode. The thin sheets thus produced must be kept constantly very warm between plates of hot iron to preserve their softness; every leaf being loaded with a weight heavy enough to prevent its warping. To join the edges of these pieces of horn together, it is necessary to provide strong iron moulds suited to the shape of the article wanted, and to place the pieces in contact with copper-plates or with polished metal surfaces against them; when this is done, the whole is to be put into a vice and screwed up tight, then plunged into boiling water, and after some time it is to be removed from thence and immersed in cold water. The edges of the horn will be thus made to cement together and become perfectly united.

To complete the polish of the horn, the surface must be rubbed with the subnitrate of bismuth by the palm of the hand. The process is short, and has this advantage, that it makes the horn dry promptly.

When it is wished to spot the horn in imitation of tortoise-shell, metallic solutions must be employed as follows:—To spot it red, a solution of gold, in aqua regia, must be employed; to spot it black, a solution of silver in nitric acid must be used; and for brown, a hot solution of mercury in nitric acid. The right side of the horn must be impregnated with these solutions, and they will assume the colors intended. The brown spots can be produced on the horn by means of a paste made of red lead, with a solution of potash, which must be put in patches on the horn, and subjected some time to the action of heat. The deepness of the brown shades depends upon the quantity of potash used in the paste, and the length of time the mixture lies on the horn. A decoction of Brazil wood, or a solution of indigo, in sulphuric acid, or a deoction of saffron, and Barbary wood may also be used. After having employed these materials, the horn may be left for half a day in a strong solution of vinegar and alum.

In France, Holland, and Austria, the comb-maker and horn-turners use the clippings of horn, which are of a whitish yellow, and tortoise-shell skins, out of which they make snuff-boxes, powder-horns, and many curious and handsome things. They first soften the horn and shell in boiling water, so as to be able to submit them to the press in iron moulds, and by means of heat form them into one mass. The degree of heat necessary to join the horn clippings must be stronger than that for shell skins, and it can only be found out by experience. The heat must not however be too great, for fear of scorching the horn or shell. Considerable care is required in these operations, not to touch the horn with the fingers, or with any greasy body, because the grease will prevent the perfect joining. Wooden instruments should be used to move them, while they are at the fire, and for carrying them to the moulds.

In making a ring of horn for bell-pulls, &c., the required piece is to be first cut out in the flat of its proper dimensions, and nearly in the shape of a horse-shoe; it is then pressed in a pair of dies to give its surface the desired pattern; but previous to the pressure, both the piece of horn and the dies are to be heated: the piece of horn is to be introduced between the dies, squeezed in a vice, and when cold, the impression or pattern will be fixed upon the horn. One particular condition, however, is to be observed in the construction of the dies, for forming a ring. They are to be so made, that the open ends of the horse-shoe piece of horn, after being pressed, shall have at one end a nib, and at the other a recess of a dovetailed form, corresponding to each other; and the second operation in forming this ring of horn is to heat it, and place it in another pair of dies, which shall bring its open ends together, and cause the dovetailed joints to be locked fast into each other, which completes the ring, and leaves no appearance of the junction.

In forming the handles of table knives and forks, or other things which require to be made of two pieces, each of the two pieces or sides of the handle is formed in a separate pair of dies; the one piece is made with a counter-sunk groove along each side, and the other piece with corresponding leaves or projecting edges. When these two pieces are formed, by the first being cut out of the flat horn, then pressed in the dies in a heated state, for the purpose of giving the pattern, the two pieces are again heated and put together, the leaves or edges of the one piece dropping into the counter-sunk grooves of the other piece, and being introduced between another pair of heated dies, the joints are pressed together and the two pieces formed into one handle.

In making the knobs for drawers which have metal stems or pins to fasten them into the furniture, the face of the knob is to be first made in a die, as above described, and then the back part of the knob with a hole in it; a metal disc of plate-iron is next provided in which the metal stem or screw pin is fixed, and the stem being passed through the aperture in the back piece, and the two, that is, the back and the front pieces of horn put together, they are then heated and pressed in dies as above described; the edge of the back piece falling into the counter-sunk groove of the front piece, while by the heat they are perfectly cemented together.

Mr. J. James has contrived a method of opening up the horns of cattle, by which he avoids the risk of scorching or frizzling, which is apt to happen in heating them over an open fire. He takes a solid block of iron pierced with a conical hole, which is fitted with a conical iron plug, heats them in a stove to the temperature of melting lead, and having previously cut up the horn lengthwise on one side with a saw, he inserts its narrow end into the hole, and drives the plug into it with a mallet. By the heat of the irons, the horn gets so softened in the course of about a minute, as to bear flatting out in the usual way.

HORNSILVER; (*Argent Corné*, or *Kerargyre*, Fr.; *Hornsilber*, Germ.) is a white or brownish mineral, sectile like wax or horn; and crystallizing in the cubic system. Its specific gravity varies from 4·75 to 5·55. Insoluble in water; not volatile; fusible at the blowpipe, but difficult of reduction by it. It deposits metallic silver when rubbed with water upon a piece of clean copper or iron. It consists of 24·67 chlorine, and 75·32 silver.

Hornsilver is rare in the European mines, but it occurs in great quantity in the districts of Zacatecas, Fresnillo, and Catarce, in Mexico: and in Huantajaya, Yauricocha, &c., in Peru; where it is abundantly mixed with the ores of hydrate of iron, called Pacos and Colorados, interspersed with veins of metallic silver, which form considerable deposits in the *penœan* limestones. There it is profitably mined as an ore of silver.

HORNSTONE; is a variety of rhomboidal quartz. Being both hard and tough, it is well adapted to form the stones of pottery mills for grinding flints; it is called chert in Derbyshire, where it abounds.

Hornstone occurs under three modifications: splintery hornstone, conchoidal hornstone, and woodstone. The colours of the first two are gray, white and red; they are all massive; dull, or of a glimmering lustre. Translucent only on the thin edges. Difficult to break. Hornstone is less brittle than flint; and by its infusibility before the blowpipe it may be distinguished from petrosilex, which it resembles in external appearance. The geological locality of hornstone is remarkable; for it occurs in both ancient and modern formations. It is found frequently in the veins that traverse primitive crystalline rocks filling up the interstices, and enveloping their metallic ores. In the lead mine of Huel goë; in Brittany it is whitish; but its prevailing colour is gray. It occurs likewise in the middle beds of the coarse limestone (*calcaire grossier*) in the Paris basin, which is a comparatively modern formation, as well as in the sand beds of the upper parts of this district, near Saint Cloud, Neuilly &c. The hornstone which occurs in secondary limestone is called *chert* by the English miners. It is valuable for forming the grinding blocks of flint mills in the pottery manufacture.

HORSE POWER, in steam engines, is estimated by Mr. Watt at 32,000 pounds avoirdupois lifted one foot high per minute, for one horse. Mr. D'Aubuisson, from an examination of the work done by horses in the whims, or gigs (*machines à molottes*) for raising ore from the mines at Freyberg, the horses being of average size and strength, has concluded that the useful effect of a horse yoked during eight hours, by two relays of four hours each, in a manege or mill course, may be estimated at 40 kilogrammes raised 1 mètre per second; which is nearly 16,440 pounds raised one foot per minute: being very nearly one-half of Mr. Watt's liberal estimates for the work of his steam engines.

Results of the Application of Horse Power to raising Water from the working Shafts at Stattwood Tunnel, on the South Eastern Railway, in 1842. By Frederick William Simms, M. Inst. C. E.—This tunnel is driven in the middle bed of the lower green sand, between which and the surface of the ground is interposed only the upper bed of the same stratum; but in sinking the eleven shafts for the work, it was found that the level of the top of the tunnel, the ground assumed the character of a quicksand, saturated with water, in such quantity that it could not be reduced by manual labour. Under these circumstances horse gins were erected for drawing the water by barrels, containing one hundred gallons each, weighing when full about 1310 lbs.

The engineer's intention was, to dive simultaneously from these shafts, in the direction of the tunnel, an adit or heading to carry off the water; but the earth, which was sand mixed with fine particles of blue clay, was so filled with water as to become a mass of semifluid mud, great exertions were therefore necessary to overcome the water, without erecting pumps. At first this was accomplished by making each horse work for 12 hours and then for 8 hours per day, allowing one hour for food and rest: as the water increased it became necessary to work night and day, and the time of each horse's working was reduced generally to 6 hours, and sometimes to 3 hours. As all the horses were hired at the rate of seven shillings per day, the author, who had the direction of the works, ordered a daily register to be kept of the actual work done by each horse, for the double purpose of ascertaining whether they all performed their duty, and also hoping to collect a body of facts relative to horse power, which might be useful hereafter. This detailed register, which was kept by Mr. P. N. Brockedon, is appended to the communication.

The author gives as a proposition, "that the proper estimate of horse power would be that which measures the weight that a horse would draw up out of a well; the animal acting by a horizontal line of traction turned into the vertical direction by a simple pulley, whose friction should be reduced as much as possible." He states that the manner in which the work was performed, necessarily approached very nearly to these conditions; and after giving the principal dimensions of the horse gins, he analyzes each set of experiments, and by taking the mean of those, against which no objections could be urged, he arrives at the following results:—

The power of a horse for 8 hours = 23,412 lbs. raised 1 foot high in one minute.
do. do. 6 = 24,360 do.
do. do. 4½ = 27,056 do.
do. do. 3 = 32,943 do.

Of these results, he thinks the experiments for 6 hours and for 3 hours alone should be adopted as practical guides, all the others being in some degree objectionable.

As a means of comparison, the following table of estimates of horse power is given:

Name.	Pounds raised 1 Foot high in a Minute.	Hours of Work.	Authority.
Boulton and Watt - - -	33,000	8	Robinson's Mech. Phil., ii. 145.
Tredgold - - - - - -	27,500	8	Tredgold on Railroads, p. 69.
Desaguliers - - - - -	44,000	8	Dr. Gregory's Mathematics for Practical Men, p. 183.
Ditto - - - - - - -	27,500	Not stated	
Saussure - - - - - -	34,020	8	
More, for Society of Arts	21,120	Not stated	
Smeaton - - - - - -	22,000	Not stated	

These are much higher results than the average of his experiments, and would more nearly accord with the extremes obtained by him; but under such excessive fatigue, the horses were speedily exhausted, and died rapidly. Nearly one hundred horses were employed; they were of good quality; their average height was 15 hands ¼ inch, and their weight about 10½ cwts., and they cost from 20*l.* to 40*l.* each. They had as much corn as they could eat, and were well attended to.

The total quantity of work done by the horses, and its cost, was as under:—

	tons.
Registered quantity of water drawn 104 feet, the average height, 28,220,800 gallons - - - - - - - -	128,535
do. earth, 3,500 yds. 1 ton 6 cwt. per yard - -	4,550
Total weight drawn to the surface - -	133,955

	£	s.	d.
Total cost of horse labour, including a boy to drive each horse -	1,585	15	3

Or 2·86*d.* per ton the average height of 104 ft.

As soon as the adit was driven, all the water was carried off by it, and the works are stated to be perfectly dry.

Mr. Palmer said, it should be understood, that in stating 32,000 lbs. raised one foot high in a minute, as the measure of the power of a horse, Boulton and Watt had not intended to fix that as the average work which horses were capable of performing: they had taken the highest results of duty performed by powerful horses, in order to convince the purchasers of their steam-engines that they received all that had been contracted for.

He had made some experiments on the amount of work performed by horses tracking boats on canals; on the upper end of the mast of the boat a pulley was hung; over this the towing rope was passed, with the means of suspending to its extremity given weights, so as exactly to balance the power exerted by the horse.

The results arrived at by these means were so various, that he could not deduce any average conclusions; as the power exerted varied between 30 lbs. and 120 lbs., the power diminishing as the speed was increased; he thought that 2½ miles was too high an average estimate, and that it should not exceed 2 miles per hour.

Mr. Field remarked that in all estimates of horse power, the speed was considered to be at an average of 2½ miles per hour, and all experiments were reduced to that standard.

Mr. Hawkins said, that some years since, he had made numerous inquiries respecting the work done by horses in drawing upon common turnpike roads, and found that four good horses could draw an ordinary stage-coach, with its complement of passengers, 8 miles a day, at the rate of 10 miles an hour; that if they ran stages 10 miles in the hour, the horses must rest one day in each week; that good horses, so worked, would last only five years, each horse drawing about half a ton: he had been informed by waggoners, that good horses would walk at the rate of 2½ miles per hour, for twelve hours out of twenty-four, making 30 miles a day; and that they would continue to do such work day by day, each horse drawing one ton, for many years, provided they had not been worked hard when young.

Mr. Gravatt observed, that although there might exist some hesitation in receiving these results of work actually performed, as a general measure of a horse's power, yet as engineers frequently required to know what could be performed by horses, when employed for short periods, in works of haste or difficulty, he thought that the experiments were useful, and would form good data for reference: he was sorry to observe that in too many cases, an idea was prevalent, that it was cheaper to work a small number of horses to death, than to keep a large number, and to work them fairly; the results which he had been enabled to arrive at, were perhaps not a fair value of a horse's work, continued for any length of time, at the best rate of economy, for both the contractor and the employer.

The President believed that however, in cases of emergency, which he allowed did occur in engineering works, the forced system of labour mentioned by Mr. Gravatt might be tolerated, he was convinced that it was not the most economical, but, on the contrary humanity and economy would be found to go hand in hand.

It would be desirable to know the average speed at which the different rates of work had been performed; this was essential in order to found any calculation upon the results given. Coach proprietors calculated that at a speed of 10 miles per hour, a horse was required for every mile going and returning, so that one horse was kept for every mile of road. Now supposing a four-horse coach, with an average load to weigh 2 tons the load for each horse was 10 cwts.; whereas in the case of a horse drawing a cart, the gross load frequently amounted to 2 tons, but the speed was reduced to 2½ miles per hour, at which pace he conceived that 16 miles per day might be considered a fair day's work; this therefore was double the distance with four times the load, or eight times the coach work, but with a heavier horse.

The law that the quantity of work done was as the square root of the velocity, or as the cube root of the velocity, in equal times, was confined to work upon canals, or bodies moving through the water.

Mr. Rennie had tried some experiments on the force of traction of the boats on the Grand Junction Canal. The towing rope was attached to a dynamometer, which had previously been tested by weights.

The horse, although urged at first starting, was afterwards allowed to fall into his natural speed, which was 2½ miles per hour on the average of 20 miles. The maximum speed was 4 miles, and the minimum 2 miles, per hour. The dynamometer indicated an average of 108 lbs., which was capable of overcoming the resistance of the loaded barge of 25 tons, being in the ratio of 15·00. The weight of the horse was about 11 cwts.

He also tried many experiments upon a fast boat, lent to him in 1833 by the late Colonel Page. These experiments were principally made in order to ascertain the comparative resistance of vessels moving through water at different velocities, and the Grand Junction Canal afforded a convenient opportunity of undertaking them.

The boat was 70 feet in length, 4 feet in breadth, and drew 9 inches of water

The traction indicated by the dynamometer the following resistance:—

Miles per hour.		lbs.
At 2½	the resistance was	20
3	"	27
3½	"	30
4	"	50
4½	"	60
5	"	70 to 75

One horse was employed in these experiments.

Miles per hour.		lbs.
At 6	the resistance was	97 to 214
7	"	250
8	"	336
9·69	"	411
10	"	375
11¼	"	392
	Average	336

Two horses were employed in these experiments.

Stakes were fixed near the margin of the canal, so as to ascertain the rise and fall of the wave caused by the boat in passing; and it was observed that when a boat passed with a velocity of from 4 to 6 miles per hour, the rise of the wave was 5 inches, and the fall 5 inches, making a wave of 10 inches in depth; and when the velocity was 11¼ miles, the rise was reduced to 2½ inches, and the fall to 2½ inches.

Great difference existed in the power of horses, their weights and structure; and the large dray horses used by Messrs. Barclay, Perkins, & Co. did a full average duty as assumed by Boulton and Watt; but considering the average power of strong and weak animals, he had adopted 22,000 lbs. raised 1 foot high as the standard; much, however, depended on the nature of the work performed.

Mr. Charles Wood remarked, that although on an emergency it might be necessary to work horses to the extent which had been mentioned, it had always been found more economical to feed them well, and not unduly to force the speed, the weight drawn, or the hours of labour. By the recorded experiments on ploughing, which were tried at Lord Ducie's and by Mr. Pusey, it was shown that any increase of speed diminished the amount of work done, in a greater ratio than it was affected by an increase of the load. In drawing loads the weight of the animal was a point of consideration and importance, and when extra exertions and muscular action were required, the nearer horses approached to "thorough bred," the greater was the result.

Mr. Davidson gave the following statement of the work performed by a London brewer's horse per day; the cost of feed and of wear and tear per horse per annum being derived from actual experience among a large number of horses at Messrs. Truman, Hanbury, & Co.'s brewery. The feed, &c. is supposed to have cost the same per quarter per truss, &c. each year.

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Years.	Pounds Weight drawn 6½ Miles per Horse per Day.	Pounds Weight drawn 6½ Miles per Horse returning per Day.	Average Pounds Weight drawn 13 Miles per Horse per Day.	Cost of Feed and Straw per Horse per Annum.	Difference per Horse of Horses bought and sold per Annum.
	Lbs.	Lbs.	Lbs.	£ s. d.	£ s. d.
1835	5,148	1,716	3,342	43 2 7	10 0 3
1836	5,072	1,767	3,389	43 16 6	9 18 0
1837					
1838	5,057	1,698	3,377	41 18 0	9 15 9
1839	5,287	1,740	3,513	42 9 11	9 7 1
1840	5,786	1,820	3,803	46 11 7	7 17 11
1841	5,311	1,750	3,530	45 0 1	10 16 11
1842	5,263	1,740	3,501	47 0 9	10 8 0
Total	36,924	12,171	24,455	309 19 5	68 3 11
Average 7 years nearly -	5,275	1,738	3,506	44 5 7	9 14 10

Mr. Horne stated that Messrs. Tredwell had a contract on the South Eastern Railway, near where Mr. Simms' experiments were made; they had upwards of 100 horses, whose average cost was about 30*l.*; they were worked 10 hours per day, and were well fed, so that their value was but little reduced, and they were eventually sold for nearly the same prices as they originally cost. These contractors had about 400 horses on the Southampton Railway, which cost them about 25*l.* each. The same course of not over-working, and of feeding them well, was pursued from motives of economy, and they found it answer.

It was Mr. Jackson's practice to keep so many horses for his work as not to be under the necessity of working them more than 10 hours per day; he gave to each a peck of corn a-day; by this means he had been able to keep up their value.

On the Chester and Crewe Railway he had about 300 horses at work, and towards the end of the contract, owing to circumstances over which he had no control, he was obliged to work them 14 or 15 hours per day; and in the course of four months horses that had been worth 25*l.* were so reduced as not to be valued at above 7*l.* He is a great advocate for steady work and good keep.

On the Tame Valley Canal there had been sometimes between 300 and 400 horses, but as the work was nearly finished, many had been sold. Those sub-contractors who had kept a sufficient number of horses for the work, so as not to have them in harness more than 12 hours per day, had realized nearly the same prices they had given for them in the first instance.

The horses belonging to Mr. Edwards, the sub-contractor for the excavation of Newton Hill, and those of Mr. W. Tredwell, sub-contractor for the Friar Park Farm cuttings, were purchased from the same parties at prices varying from 20*l.* to 35*l.* The former had been acting on the principle of getting out of the horses all he could, working them frequently 15 and 16 hours at a time; and the consequences were, that all his stock was in bad condition, and he would be glad to get 6*l.* or 7*l.* a-piece for them. On the other hand, Mr. W. Tredwell, who was an excellent horse master, and who did not work his horses beyond their strength, would be able to sell them for about as much as he gave for them,—indeed he had done so already for those that he had parted with.

Having been a good many years in the service of the late Mr. McIntosh, Mr. Horne could state that it never was his system to over-work his horses. It did sometimes happen that there was no alternative, but the deviation from the regular rule in every instance showed that his system was founded on right principles. The over-worked horses were most liable to disease, and the time lost by illness formed an important item; whereas there were plenty of instances in which horses that had worked their regular 10 hours per day, and had been properly fed, had worked for five or six years without losing a single day by illness. On the whole he felt convinced, that both on the score of humanity and economy, the horse was the more valuable servant when treated with kindness.

Mr. Beardmore said that a case had occurred in a work near Plymouth, which he believed would give the fair value of the work actually performed daily by a horse for a considerable period.

A quarry-wagon, weighing 2½ tons, carrying an average load of stone of 5¾ tons, was drawn by one horse along a railway 960 feet in length, 260 of it being level, and the remaining 700 feet having an inclination of 1 in 138. During 48 working days the number

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of trips was 1,302, or an average of 27·1 trips each day; the time of performing each trip was 4 minutes, or at a speed of 2·72 miles per hour; and the total weight drawn including that of the waggons, was 23,959,600 lbs.

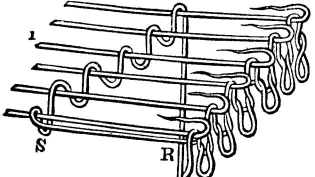
Repeated experiments proved, that upon the incline of 1 in 138 the waggons in their ordinary working state would just remain stationary; the friction was therefore assumed to be 16·2 lbs. per ton; by calculation it was found that the horse raised 39,320 lbs. 1 foot high per minute during the 8 working hours each day: the useful effect, or net amount of stone carried, being 21,738 lbs. raised 1 foot high per minute. This difference between the work done and the useful effect arose from the necessary strength and weight of the waggons.

The animal employed was a common Devonshire cart-horse, 8 years old, 15 hands high, and weighed 10¾ cwts.; he continued doing the same work throughout a whole summer, remaining in good condition; but a lighter horse was found unequal to it.

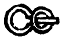
HOSIERY (*Bonneterie*, Fr.; *Strumpfweberei*, Germ.). The *stocking frame*, which is the great implement of this business, though it appears at first sight to be a complicated machine, consists merely of a repetition of parts easily understood, with a moderate degree of attention, provided an accurate conception is first formed of the nature of the hosiery fabric. This texture is totally different from the rectangular decussation which constitutes cloth, as the slightest inspection of a stocking will show; for this, instead of having two distinct systems of thread, like the warp and the weft, which are woven together, by crossing each other at right angles, the whole piece is composed of a single thread united or looped together in a peculiar manner, which is called stocking-stitch, and sometimes chain-work.

This is best explained by the view in *fig.* 760. A single thread is formed into a number of loops or waves; by arranging it over a number of parallel needles, as shown at R: these are retained or kept in the form of loops or waves, by being drawn or looped through similar loops or waves formed by the thread of the preceding course of the work, S. The fabric thus formed by the union of a number of loops is easily unravelled, because the stability of the whole piece depends upon the ultimate fastening of the first end of the thread; and if this is undone, the loops formed by that end will open, and release the subsequent loops, one at a time, until the whole is unravelled, and drawn out into the single thread from which it was made. In the same manner, if a thread in a stocking-piece fails, or breaks at any part, or drops a stitch, as it is called, it immediately produces a hole, and the extension of the rest can only be prevented by fastening the end. It should be observed that there are many different fabrics of stocking-stitch for various kinds of ornamental hosiery, and as each requires a different kind of frame or machine to produce it, we should greatly exceed our limits to enter into a detailed description of them all. That species which we have represented in *fig.* 760 is the common stocking-stitch used for plain hosiery, and is formed by the machine called the common stocking-frame, which is the groundwork of all the others. The operation, as we see, consists in drawing the loop of a thread successively through a series of other loops, so long as the work is continued, as is very plainly shown for one stitch in *fig.* 761.

760



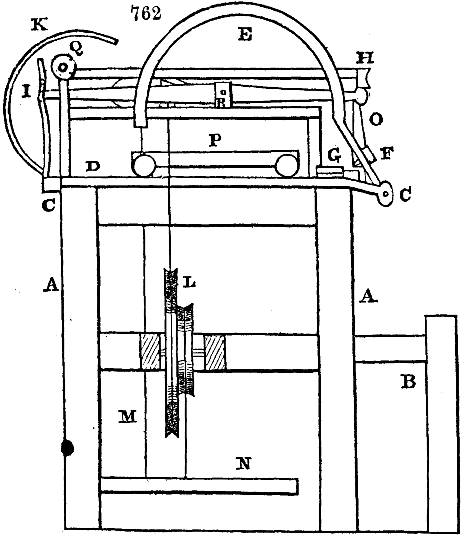
761



There is a great variety of different frames in use for producing various ornamental kinds of hosiery. The first, which forms the foundation of the whole, is that for knitting plain hosiery, or the common stocking-frame.

Of this valuable machine, the invention of Mr. Lee, of Cambridge, a side elevation is given in *fig.* 762, with the essential parts. The framing is supported by four upright posts, generally of oak, ash, or other hard wood. Two of these posts appear at A A, and the connecting cross rails are at C C. At B is a small additional piece of framing, which supports the hosier's seat. The iron-work of the machine is bolted or screwed to the upper rails of the frame-work, and consists of two parts. The first rests upon a sole of polished iron, which appears at D, and to which a great part of the machinery is attached. The other part, which is generally called the carriage, runs upon the iron sole at D, and is supported by four small wheels, or trucks, as they are called by the workmen. At the upper part of the back standard of iron are joints, one of which appears at Q; and to these is fitted a frame, one side of which is seen extending to H. By means of these joints, the end at H may be depressed by the hosier's hand, and it returns, when relieved, by the operation of a strong spring of tempered steel, acting between a cross bar in the frame and another below. The action of this spring is very apparent in *fig.* 763. In the front of the frame, immediately opposite to where the hosier sits, are placed the needles which form the loops. These needles, or rather hooks, are more or less numerous, according to the coarseness or fineness of the stocking; and this, although unavoidable, proves a very considerable abatement of the value of a stocking-frame. In almost every other machine (for example, those employed in spinning or weaving), it is easy to adapt any one either to work coarser or finer work, as it may be wanted. But in the manufacture of hosiery, a frame once finished, is limited for ever in its operation to the same quality of work, with this exception, that by changing the stuff, the work may be made a little more dense or flimsy; but no alteration in the size or quantity of loops can take place. Hence where the manufacture is extensively prosecuted, many frames may be thrown idle by every vicissitude of demand; and where a poor mechanic does purchase his own frame, he is for ever limited to the same kind of work. The gauge, as it is called, of a stocking-frame is regulated by the number of loops contained in three inches of breadth, and varies very much; the coarsest frames in common use being about what are termed Fourteens, and the finest employed in great extent about Forties. The needles are of iron wire, the manufacture of which is very simple; but long practice in the art is found necessary before a needle-maker acquires the dexterity which will enable him both to execute his work well, and in sufficient quantity to render his labor productive.

762



The process of making the needles is as follows:—Good sound iron wire, of a proper fineness, is to be selected; that which is liable to split or splinter, either in filing, punching, or bending, being totally unfit for the purpose. The wire is first to be cut into proper lengths, according to the fineness of the frame for which the needles are designed, coarse needles being considerably longer than fine ones. When a sufficient number (generally some thousands) have been cut, the wire must be softened as much as possible. This is done by laying them in rows in a flat iron box, about an inch deep, with a close cover; the box being filled with charcoal between the strata of wires. This box, being placed upon a moderate fire, is gradually heated until both the wires and charcoal have received a moderate red heat, because, were the heat increased to what smiths term the white heat, the wire would be rendered totally unfit for the subsequent processes which it has to undergo, both in finishing and working. When the box has been sufficiently heated, it may be taken from the fire, and placed among hot ashes, until both ashes and box have gradually cooled; for the slower the wires cool, the softer and easier wrought they will be. When perfectly cool, the next process is to punch a longitudinal groove in the stem of every needle, which receives the point or barb, when depressed. This is done by means of a small engine worked by the power of a screw and lever. The construction of these engines is various; but a profile elevation of one of the most simple and commonly used will be found in *fig*. 763. It consists of two very strong pieces of malleable iron, represented at A and C, and these two pieces are connected by a strong well-fitted joint at B. The lower piece, or sole of the engine at C, is screwed down by bolts to a strong board or table, and the upper piece A will then rise or sink at pleasure, upon the joint B. In order that A may be very steady in rising and sinking, which is indispensable to its correct operation, a strong bridle of iron, which is shown in section at E, is added to confine it, and direct its motion. In the upper part of this bridle is a female screw, through which the forcing screw passes, which is turned by the handle or lever D. To the sole of the engine C is fixed a bolster

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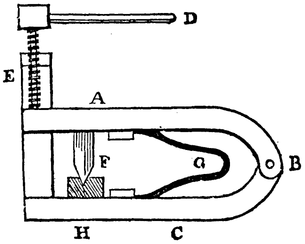

of tempered steel, with a small groove to receive the wire, which is to be punched; and in the upper or moving part A, is a sharp chisel, which descends exactly into the groove, when A is depressed by the screw. These are represented at F, and above H. At G is a strong spring, which forces up the chisel when the pressure of the screw is removed. The appearance of the groove, when the punching is finished, will be rendered familiar by inspecting *fig*. 764, p. 1022. When the punching is finished, the wires are to be brought to a fine smooth point by filing and burnishing, the latter of which should be very completely done, as, besides polishing the wire, it tends greatly to restore that spring and elasticity which had been removed by the previous operation of softening. The wire is next to be bent, in order to form the hook or barb; and this is done with a small piece of tin plate bent double, which receives the point of the wire, and by its breadth regulates the length of the barb. The stem of the needle is now flattened with a small hammer, to prevent it from turning in the tin socket in which it is afterwards to be cast; and the point of the barb being a little curved by a pair of small pliers, the needle is completed.

In order to fit the needles for the frame, they are now cast into the tin sockets, or leads, as they are called by the workmen; and this is done by placing the needles in an iron mould, which opens and shuts by means of a joint, and pouring in the tin while in a state of fusion. In common operations, two needles are cast into the same socket. The form of the needle, when complete and fitted to its place in the frame, will be seen in *fig*. 765, which is a profile section of the needle-bar, exhibiting one needle. In this figure a section of the pressure is represented at F; the needle appears at G, and the socket or level at K. At H, is a section of the needle-bar, on the fore part of which is a small plate of iron called a verge, to regulate the position of the needles. When placed upon the bar resting against the verge, another plate of iron, generally lined with soft leather, is screwed down upon the sockets or leads, in order to keep them all fast. This plate and the screw appear at I. When the presser at F is forced down upon the barb, this sinks into the groove of the stem, and the needle is shut; when the presser rises, the barb opens again by its own elasticity.

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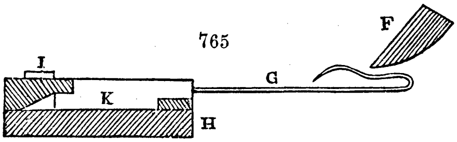
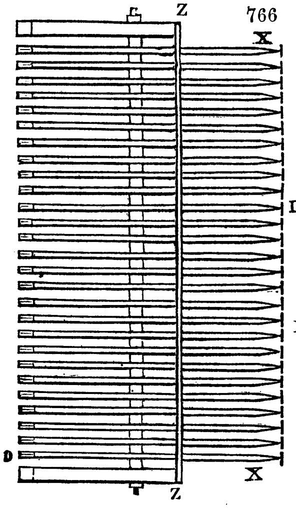


The needles or hooks being all properly fitted, the next part of the stocking-frame to which attention ought to be paid, is the machinery for forming the loops; and this consists of two parts. The first of these, which sinks between every second or alternate needle, is represented at O, *fig*. 762, and is one of the most important parts of the whole machine. It consists of two moving parts; the first being a succession of horizontal levers moving upon a common centre, and called jacks, a term applied to vibrating levers in various kinds of machinery as well as the stocking-frame. One only of these jacks can be represented in the profile *fig*. 762; but the whole are distinctly shown in a horizontal position in *fig*. 766; and a profile upon a very enlarged scale is given in *fig*. 767.

766



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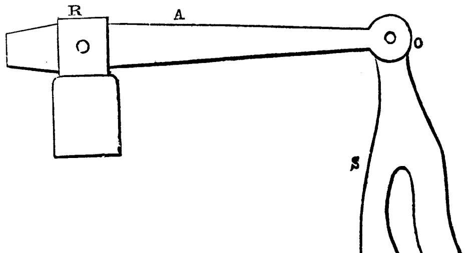

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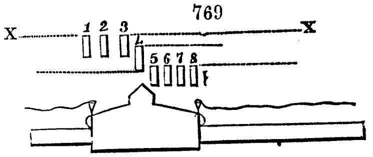

The jack shown in *fig*. 762, extends horizontally from O to I, and the centre of motion is at R. On the front, or right hand part of the jack at O, is a joint suspending a very thin plate of polished iron, which is termed a sinker. One of these jacks and sinkers is allotted for every second or alternate needle. The form of the sinker will appear at S, *fig*. 767; and in order that all may be exactly uniform in shape, they are cut out and finished between two stout pieces of iron, which serve as moulds or gauges to direct the frame-smith. The other end of the jack at ., is tapered to a point; and when the jacks are in their horizontal position, they are secured by small iron springs, one of which is represented at I, *fig*. 762, each spring having a small obtuse angled notch to receive the point of the jack, against which it presses by its own elasticity. In *fig*. 767 the centre is at R; the pointed tail is omitted for want of room, the joint is at O, and the throat of the sinker, which forms the loop, is at S. The standards at R, upon which the jack moves, are called combs, and consist of pieces of flat smooth brass, parallel to, and equidistant from each other. The cross-bar R, which contains the whole, is of iron, with a perpendicular edge or rim on each side, leaving a vacancy between them, or a space to receive the bottom part or tails of the combs. The combs are then placed in the bar, with a flat piece of brass called a countercomb, between each, to ascertain and preserve their distances from each other. These countercombs are exactly of the same shape as the combs, but have no tails. When both combs and countercombs are placed in the bar, it is luted with clay so as to form a mould, into which is poured a sufficient quantity of melted tin. When the tin has had time to cool, the countercombs having no tails are easily taken out, and the combs remain well fastened and secured by the tin, which has been fused entirely round them. Thus they form a succession of standards for the jacks; and a hole being drilled through each jack and each comb, one polished wire put through, serves as a common centre for the whole.

The jack sinkers being only used for every alternate or second needle, in order to complete this part of the apparatus, a second set of sinkers is employed. These are, in form and shape, every way the same as the jack sinkers, but they are jointed at the top into pieces of tin, all of which are screwed to the sinker bar H, *fig*. 762; and thus a sinker of each kind descends between the needles alternately. By these sinkers the loops are formed upon all the needles, and the reason of two sets different in operation being employed, will be assigned in describing the mode of working the frame. The presser of the operation, of which something has already been said, appears at F; and of the two arms which support and give motion to it, one appears very plainly at E, its centre of motion being at C. The circular bend given to these arms, besides having an ornamental effect, is very useful, in order to prevent any part from interfering with the other parts which are behind, by elevating them entirely above them. The extremities of these arms at the termination of the bends behind, are connected by a cross bar, which has also a circular bend in the middle, projecting downwards, for a reason similar to that already assigned. This bend is concealed in *fig*. 762, but visible in the front elevation, *fig*. 768. From the middle of the bend, the presser is connected with the middle treadle by a depending wire appearing at M, *fig*. 762, and thus, by the pressure of that treadle, the presser is forced down to close the barbs of the needle. The re-ascent of the presser is sometimes effected by means of a counterpoising weight passing over a pulley behind; and sometimes by the reaction of a wooden spring, formed of a strong hoop like that represented at K. The latter of these is preferred, especially by the Nottingham hosiers, because, as they assert, it makes the presser spring up with greater

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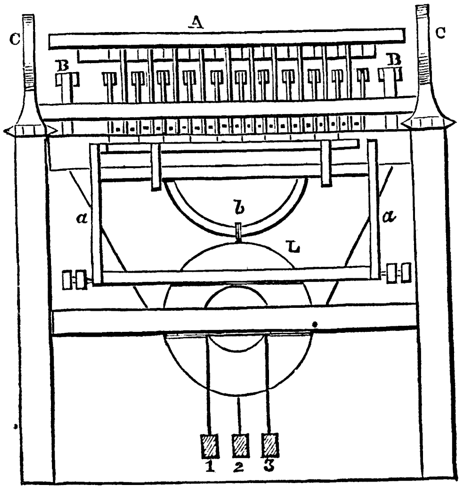

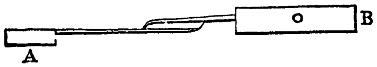

764

rapidity, and consequently saves time in working. How far this may be practically the case, it would be superfluous here to investigate; but it is obvious that the wooden spring, if very stiff, must add much to the hosier's exertion of his foot, already exercised against the united spring of all his barbs; and this inconvenience is much complained of by those who have been accustomed to work with the counterpoise.

At L are two pulleys or wheels, of different diameters, moving upon a common centre, by which the jack sinkers are relieved from the back springs, and thrown downwards to form the loops upon the needles. About the larger wheel is a band of whipcord, passing twice round, the extremities of which are attached to what is called the slur, which disengages the jacks from the back springs. The smaller pulley, by another band, communicates with the right and left treadle; so that these treadles, when pressed alternately, turn the pulleys about in an inverted order. The directions of these bands also appear more plainly in the front elevation, *fig.* 768. The construction of the slur, and its effect upon the jacks, will also be rendered apparent by *fig.* 769. In this figure, eight jacks are represented in section, the tail part of three of which, 1, 2, 3, are thrown up by the slur in its progress from left to right; the fourth is in the act of rising, and the remaining four, 5, 6, 7, and 8, are still unacted upon, the slur not yet having reached them. As the slur acts in the direction of the dotted line x, x, *fig.* 766, behind the centres of the jacks, it is hardly necessary to remark, that this forcing up of the tails must of course depress the joints by which the sinkers in front are suspended. The jack sinkers falling successively from the loops on every alternate needle, in the way represented at *fig.* 770, where both kinds of sinkers appear in section, the light part expressing what is above the point at which the throat of the sinker operates upon the thread, and the dark part what is below. The second set, or, as they are called, the lead sinkers, from the manner of jointing them, and suspending them from the bar above, appear still elevated; the position of the bar being represented by the line A, B. But when these are pulled down to the level of the former by the operator's hands, the whole looping will be completed, and the thread C, D, which is still slack, will be brought to its full and proper degree of tension, which is regulated by stop screws, so as to be tempered or altered at pleasure.

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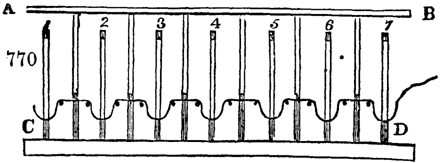

The sinking of this second set of sinkers, may be easily explained by *fig.* 771. The direction of the sinkers is expressed by the line E; the bar from which they are suspended will be at A; the top frame is in the direction from A to B; the back standards at D, and the joint at B, is the centre of motion. If E is pulled perpendicularly downwards, the spring C will be contracted, and its upper extreme point G, will be brought nearer to its lower extreme point F, which is fixed. Again, when the force which has depressed E is removed, the spring C will revert to its former state, and the sinkers will rise. The raising of the jack sinkers and jacks takes place at the same time, by the hosier raising his hands; and for the cause of this we must revert to *fig.* 766. The lead sinkers in rising lay hold of notches, which raise the extreme parts of the set of jacks z, z, which are called half-jacks. Between the extremities of these at z, z, is a cross bar, which, in descending, presses all the intermediate jacks behind the common centre, and restores them to their original posture, where they are secured by the back springs, until they are again relieved by the operation of the slur recrossing at the next course.

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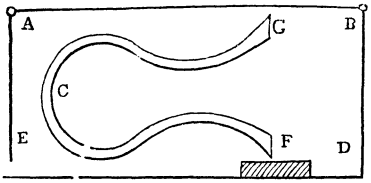

Working of the frame.—In order to work a frame, the whole apparatus being previously put into complete order, the hosier places himself on the seat B in front, and provides himself with a bobbin of yarn or stuff. This bobbin he places loosely on a vertical pin of wire, driven into one side of the frame contiguous to the needles, so that it may turn freely as the stuff is unwound from it. Taking the thread in his hand, he draws it loosely along the needles, behind the barbs, and under the throats of the sinkers. He then presses down one of the treadles to pass the slur along, and unlock the jacks from the back springs, that they may fall in succession. When this is done, the number of loops thus formed is doubled by bringing down the lead sinkers, and the new formed loops are lodged under the barbs of the needles by bringing forward the sinkers. The preceding course, and former fabric, being then again pushed back, the barbs are shut by depressing the middle treadle, and forcing down the presser upon the needles. The former work is now easily brought over the shut needles, after which by raising the hands, both sets of sinkers are raised; the jacks are locked by the back springs, and the hosier goes on to another course.

From this it will be apparent, that the remark made in the outset is well founded, that there are, in reality, no complicated or difficult movements in the stocking-frame. Almost the whole are merely those of levers moving upon their respective fulcra, excepting that of the carriage which gives the horizontal motion to the sinkers, and that is merely an alternate motion on four wheels. Yet the frame is a machine which requires considerable experience and care, both to work it to advantage, and also to keep it in good order. This circumstance arises greatly from the small compass in which a number of moving parts must be included. Owing to this, the needles, unless cautiously and delicately handled, are easily bent or injured. The same circumstance applies with equal or greater force to the sinkers, which must be so very thin as to be easily injured. But as these must work freely, both in a perpendicular and horizontal direction between the needles, in a very confined and limited space, the slightest variation in either, from being truly and squarely placed, unavoidably injures the others. When a hosier, either ignorant of the mechanical laws, of their relation to each other, or too impatient to wait for the assistance of another, attempts to rectify defects, he in most cases increases them tenfold, and renders the machine incapable of working at all, until repaired by some more experienced person. This circumstance has given rise to a set of men employed in this trade, and distinguished by the name of upsetters; and these people, besides setting new frames to work, have frequently more employment in repairing old ones injured by want of care or skill, than many country apothecaries, who live in unhealthy parishes, find in tampering with the disorders of mankind.

It seems unnecessary to go further into detail respecting a machine so well known, and which requires practical attention even more than most others. It may, therefore, be sufficient to describe shortly some of its varieties, the most simple and common of which is the rib stocking-frame.

Rib stocking-frame.—This frame, which, next to the common frame, is most extensively in use, is employed for working those striped or ribbed stockings, which are very common in all the different materials of which hosiery is formed. In principle it does not differ from the common frame, and not greatly in construction. The preceding general description will nearly apply to this machine with equal propriety as to the former; that part, however, by which the ribs or stripes are formed, is entirely an addition, and to the application of this additional machinery it may be proper to pay the chief attention, referring chiefly to *fig.* 768, which is a front elevation.

This figure has been already referred to for the illustration of those parts of the machinery which are common to both, and those parts therefore require no recapitulation. The principle of weaving ribbed hosiery possesses considerable affinity to that which subsists in the weaving of that kind of cloth which is distinguished by the name of tweeling, for the formation of stripes, with some variation arising merely from the different nature of the fabric. In cloth weaving, two different kinds of yarn intersecting each other at right angles, are employed; in hosiery only one is used. In the tweeling of cloth, striped as dimity, in the cotton or kerseymere, and in the woollen manufacture, the stripes are produced by reversing these yarns. In hosiery, where only one kind of yarn is used, a similar effect is produced by reversing the loops. To effect this reversing of the loops, a second set of needles is placed upon a vertical frame, so that the bends of the hooks may be nearly under those of the common needles. These needles are cast into tin moulds, pretty similar to the former, but more oblique or bevelled towards the point, so as to prevent obstructions in working them. They are also screwed to a bar of iron, generally lighter than the other, and secured by means of plates: this bar is not fixed, but has a pivot in each end, by means of which the bar may have a kind of oscillatory motion on these pivots. The two frames of iron support this bar; that in which it oscillates being nearly vertical, but inclined a little towards the other needles. *Fig.* 772, which is a profile elevation, will serve to illustrate the relative position of each bar to the other. The lower or horizontal frame, the ends only of which can be seen in *fig.* 768 under *a a*, appears in profile in *fig.* 772, where it is distinguished by *d*. The vertical frame at *a* is attached to this by two centre screws, which serve as joints for it to move in. On the top of this frame is the rib-needle bar at *f*, in *figs.* 762 and 772, and one needle is represented in *fig.* 772 at *f*. At *g* is a small presser, to shut the barbs of the rib-needles, in the same manner as the large one does those of the frame. At *h* is one of the frame needles, to show the relative position of the one set to the other. The whole of the rib-bar is not fitted with needles like the other; for here needles are only placed where ribs or stripe are to be formed, the intervals being filled up with blank leads, that is

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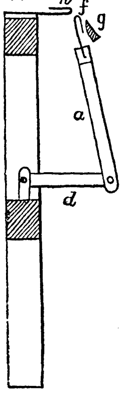

to say, with sockets of the same shape as the others, but without needles; being merely designed to fill the bar and preserve the intervals. Two small handles depend from the needle bar, by which the oscillatory motion upon the upper centres is given. The rising and sinking motion is communicated to this machine by chains which are attached to iron sliders below, and which are wrought by the hosier's heel when necessary. The pressure takes place partly by the action of the small presser, and partly by the motion of the needles in descending. A small iron slider is placed behind the rib-needles, which rises as they descend, and serves to free the loops perfectly from each other.

In the weaving of ribbed hosiery, the plain and rib courses are wrought alternately. When the plain are finished, the rib-needles are raised between the others, but no additional stuff is supplied. The rib-needles, intersecting the plain ones, merely lay hold of the last thread, and, by again bringing it through that which was on the rib-needle before, give it an additional looping, which reverses the line of chaining, and raises the rib above the plain intervals, which have only received a single knitting.

HOT-FLUE is the name given in England to an apartment heated by stoves or steam pipes, in which padded and printed calicoes are dried hard. *Fig.* 773 represents the simplest form of such a flue, heated by the vertical round iron stove C, from whose top a wide square pipe proceeds upwards in a slightly inclined direction, which receives the current of air heated by the body and capital of the stove. In this wide channel there are pulleys, with cords or bands which suspend by hooks, and conduct the web of

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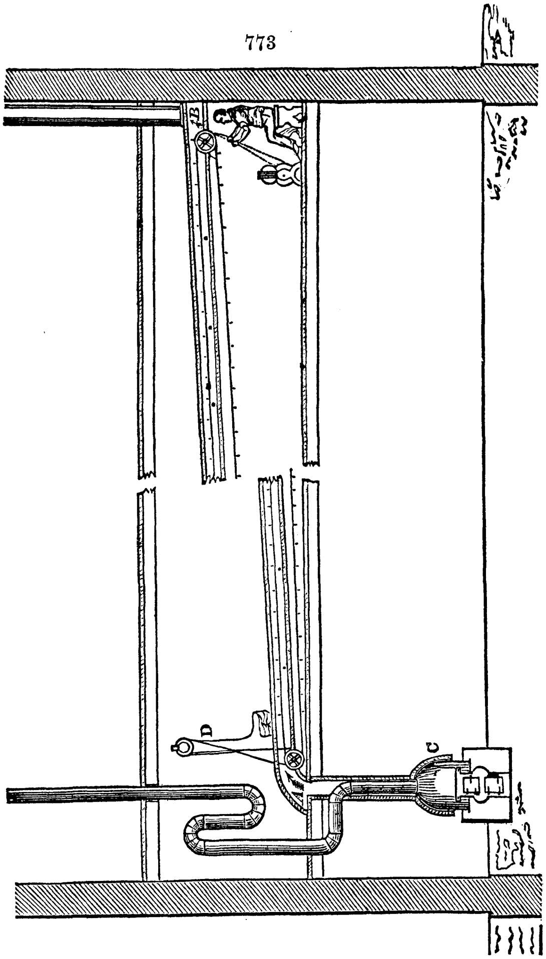

calico, from the entrance at B, where the operative sits, to near the point A, and back again. This circuit may be repeated once or oftener till the goods are perfectly dried. At D the driving pulley connected with the main shaft is shown. Near the feet of the operative is the *candroy* or reel upon which the moist goods are rolled in an endless web; so that their circulation in the hot-air channel can be continued without interruption, as long as may be necessary.

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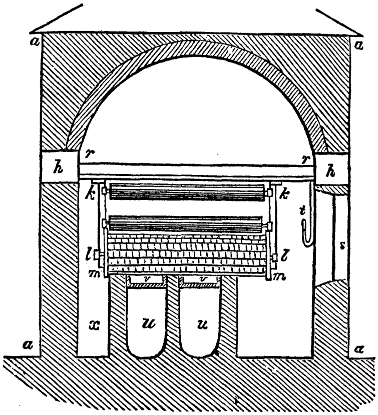

Fig. 774 is a cross section of the apparatus of the regular hot-flue, as it is mounted in the most scientific calico works of England, those of James Thomson, Esq., of Primrose, near Clitheroe, Lancashire. *a a a a*, is an arched apartment, nearly 30 yards long, by 13 feet high, and 10 feet wide. Through about one half of this gallery there is a horizontal floor supported on arches, above which is the driest space, through which the goods are finally passed before they escape from the hot-flue, after they have been previously exposed to the hot but somewhat moist air of the lower compartment. A large square flue covered with cast-iron plates runs along the whole bottom of the gallery. It is divided into two long parallel vaults, whose sections are seen at *u*, *u*, *fig.* 774, covered with the cast-iron plates *v v*, grooved at their ends into one another. The thickness of these plates is increased progressively as they come nearer to the fire-place or furnace. There are dampers which regulate the draught, and of course the heat of the stove. *h h* are the air-passages or vent-holes, left in the side walls, and which by means of a long iron rod, mounted with iron plates, may be opened or closed together to any degree. *k k* are the cast-iron supports of the tinned brass rollers which guide the goods along, and which are fixed to the cross pieces represented by *r r*, *fig.* 774. *l l* are iron bars for supporting the ventilators or fans (see the fan under Foundry). These fans are here enclosed within a wire grating. They make about 300 turns per minute, and expel the moist air with perfect effect. *s* indicates the position of the windows, which extend throughout the length of the building. *t* is a gas-light jet, placed at the side of each window to supply illumination for night work.

The piece is stretched along the whole extent of the gallery, and runs through it in the course of one minute and a half; being exposed during its passage to the heat of 212° Fahr.

In *fig.* 775, A is the iron door of entrance to the hot-flue gallery; at *b* is the padding machine, where the goods are imbued with the general mordant. The speed of this machine may be varied by means of the two conical drums *c c*, which drive it; since when the band *c c* is brought, by its forks and adjusting screws, nearer to the narrow end of the lower drum, the cylinder upon the same shaft with the latter is driven quicker; and *vice versa*. Over D D the cords are shown for drawing the drum mechanism into gear with the main shaft band, F F E; or for throwing it out of gear. The pulleys F F carry the bands which transmit the motion to the padding machine. A cylindrical drum exterior to the hot-flue, covered with flannel, serves to receive the end of the series of pieces, and to draw them through the apartment. This mode of drying

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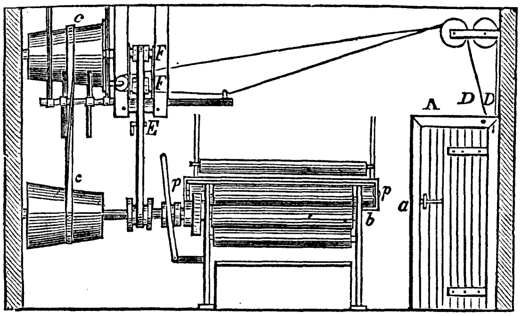


the padded calicoes requires for each piece of 28 yards, 3 pounds of coals for the furnace when a fan is employed, and four pounds without it.

HYDRATES; are compounds of the oxides, salts, &c. with water in definite or equivalent proportions. Thus slaked lime consists of one atom of quick-lime = 28, + one atom of water = 9, of which the sum is 37 on the hydrogen scale.

HYDRAULIC PRESS. See Oil, Press, and Stearine.

HYDRYODIC ACID; (*Acide Hydriodique*, Fr.; *Hydriodsäure*, Germ.) is an acid formed by the combination of 99·21 parts of iodine, and 0·79 hydrogen. When pure, it occurs in the gaseous state, but it combines with water, like the hydrochloric or muriatic acid gas, into a liquid acid.

HYDROCHLORIC ACID; the new chemical name of muriatic acid, which see.

HYDROGEN; (Eng. and Fr.; *Wasserstoff*, Germ.) an undecompounded gaseous body; the lightest of all ponderable matter, whose examination belongs to chemistry.

HYDROMETER; an instrument for ascertaining the specific gravities of liquids. Baumé's hydrometer, which is much used in France, and other countries of the continent of Europe, when plunged in pure water, at the temperature of 58° Fahr., marks 0 upon its scale; in a solution containing 15 per cent. of common salt (chloride of sodium), and 85 of water by weight, it marks 15°; so that each degree is meant to indicate a density corresponding to one per cent. of that salt. See Areometer, for comparative tables of hydrometers.

HYDROSULPHURETS; chemical compounds of bases with sulphuretted hydrogen.

HYMENŒA COURBARIL; a tree growing in South America, from which the resin *animé* exudes.

HYOSCIAMUS NIGER. Henbane is a plant used in medicine, from which modern chemistry has extracted a new crystalline vegetable principle called *hyosciamine*, which is very poisonous, and when applied in solution to the eye, determines a remarkable dilatation of the pupil; as *belladonna* also does.

HYPOSULPHATES; Hyposulphites; saline compounds of the hyposulphuric or hyposulphurous acid with bases.

HYPEROXYMURIATES; the old and incorrect name for Chlorates.

HYPOSULPHATE OF SODA. Pure crystallized carbonate of soda is dried as much as possible, and reduced to a fine powder; 1 lb. of it is then mixed with 10 ozs. of flowers of sulphur, and the mixture is heated in a glass or porcelain dish, gradually, until the sulphur melts. The mass which cakes together is kept at this temperature and is divided, stirred and mixed, in order that each part may be brought into contact with the atmosphere. The sulphuret of sodium formed passes, under these circumstances, by the absorption of oxygen from the atmosphere, with a slight incandescence, gradually into sulphite of soda. It is dissolved in water; filtered, the liquid immediately boiled with flowers of sulphur; the filtered, nearly colourless, strongly concentrated liquid affords hyposulphate of soda in very pure and beautiful crystals, and in large quantity.

When the mixture is heated too quickly, some sulphur is easily burnt; there then remains a portion of undecomposed carbonate of soda, which contaminates the hyposulphite in the first crystallization, but which may very readily be separated from it.

HYPOSULPHITE OF SODA. This salt, so extensively used in the practice of *Daguerreotyping*, may be easily prepared in quantities by the following process:—Mix one pound of finely pulverised ignited carbonate of soda with ten ounces of flowers of sulphur, and heat the mixture slowly in a porcelain dish till the sulphur melts. Stir the fused mass so as to expose all its parts freely to the atmosphere, whereby it passes from the state of a sulphuret, by the absorption of atmospherical oxygen, into that of a sulphite, with the phenomenon of very slight incandescence. Dissolve in water, filter the solution, and boil it immediately along with flowers of sulphur. The filtered concentrated saline liquid will afford, on cooling, a large quantity of pure and beautiful crystals of hyposulphite of soda.

I. & J.

JACK, called also *jack in a box*, and *hand-jack*, is a portable, mechanical instrument, consisting of a rack and pinion, or a pair of claws and ratchet bar, moved by a winch handle for raising heavy weights a little way off the ground.

JACK and JACK-SINKERS, are parts of a stocking frame. See Hosiery.

JACK-BACK, is the largest jack of the brewer.

JACQUARD. A peculiar and most ingenious mechanism, invented by M. Jacquart of Lyons, to be adapted to a silk or muslin loom for superseding the employment of draw-boys, in weaving figured goods. Independently of the ordinary play of the warp threads for the formation of the ground of such a web, all those threads which should rise simultaneously to produce the figure, have their appropriate healds, which a child formerly raised by means of cords, that grouped them together into a system, in the order, and at the time desired by the weaver. This plan evidently occasioned no little complication in the machine, when the design was richly figured; but the apparatus of Jacquart, which subjects this manœuvre to a regular mechanical operation, and derives its motion from a simple pedal put in action by the weaver's feet, was generally adopted soon after its invention in 1800. Every common loom is susceptible of receiving this beautiful appendage. It costs in France 200 francs, or 8*l.* sterling, and a little more in this country.

Fig. 776. is a front elevation of this mechanism, supposed to be let down. *Fig.* 777. is a cross section, shown in its highest position. *Fig.* 778. the same section as the preceding, but seen in its lower position.

A, is the fixed part of the frame, supposed to form a part of the ordinary loom; there are two uprights of wood, with two cross-bars uniting them at their upper ends, and leaving an interval *x y* between them, to place and work the movable frame B, vibrating round two fixed points *a a*, placed laterally opposite each other, in the middle of the space *x y*, *fig.* 776.

C, is a piece of iron with a peculiar curvature, seen in front, *fig.* 776., and in profile, *figs.* 777. and 778. It is fixed on one side upon the upper cross-bar of the frame B, and on the other, to the intermediate cross-bar *b* of the same frame, where it shows an inclined curvilinear space *c*, terminated below by a semicircle.

D, is a square wooden axis, movable upon itself round two iron pivots, fixed into its two ends; which axis occupies the bottom of the movable frame B. The four faces of this square axis are pierced with three round, equal, truly-bored holes, arranged in a quincunx. The teeth *a*, *fig.* 780., are stuck into each face, and correspond to holes *a*, *fig.* 783., made in the cards which constitute the endless chain for the healds; so that in the successive application of the cards to each face of the square axis, the holes pierced in one card may always fall opposite to those pierced in the other.

The right-hand end of the square axis, of which a section is shown in double size, *fig.* 779., carries two square plates of sheet iron *d*, kept parallel to each other and a little apart, by four spindles *e*, passed opposite to the corners. This is a kind of lantern, in whose spindles, the hooks of the levers *f f'*, turning round fixed points *g g'* beyond the right hand upright A, catch hold, either above or below at the pleasure of the weaver, according as he merely pulls or lets go the cord *z*, during the vibratory movement of the frame B.

E is a piece of wood shaped like a T, the stem of which prolonged upwards, passes freely through the cross-bar *b*, and through the upper cross-bar of the frame B, which serves as guides to it. The head of the T piece being applied successively against the two spindles *e*, placed above in a horizontal position, first by its weight, and then by the spiral spring *h*, acting from above downwards, keeps the square axis in its position, while it permits it to turn upon itself in the two directions. The name *press* is given to the assemblage of all the pieces which compose the movable frame B B.

F is a cross-bar made to move in a vertical direction by means of the lever G, in the notches or grooves *i*, formed within the fixed uprights A.

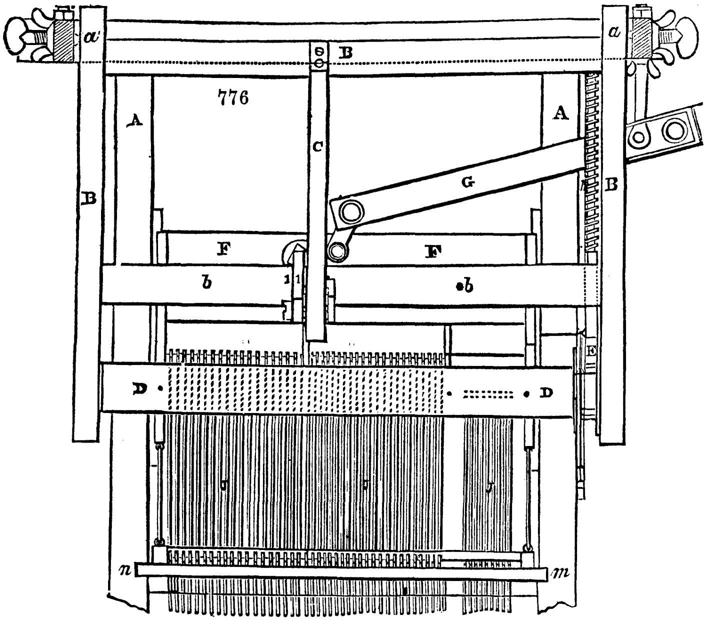
H, is a piece of bent iron, fixed by one of its ends with a nut and screw, upon the cross-bar F, out of the vertical plane of the piece C. Its other end carries a friction roller J, which working in the curvilinear space *c* of the piece C, forces this, and consequently the frame B, to recede from the perpendicular, or to return to it, according as the cross-bar F is in the top or bottom of its course, as shown in *figs.* 777. and 778.

I, cheeks of sheet iron attached on either side to the cross-bar F, which serves as a safe to a kind of claw K, composed here of eight small metallic bars, seen in section *fig.* 777. and 778., and on a greater scale in *fig.* 780.

J, upright skewers of iron wire, whose tops bent down hook-wise naturally place themselves over the little bars K. The bottom of these spindles likewise hooked in the same direction as the upper ones, embraces small wooden bars *l*, whose office is to keep them in their respective places, and to prevent them from twirling round, so that the uppermost hooks may be always directed towards the small metallic bars upon which they impend. To these hooks from below are attached strings, which after having crossed a fixed board *m n*, pierced with corresponding holes for this purpose, proceed next to be attached to the threads of the loops destined to lift the warp threads. K K, horizontal spindles or needles, arranged here in eight several rows, so that each spindle corresponds both horizontally and vertically to each of the holes pierced in the four faces of the square axis D. There are therefore as many of these spindles as there are holes in one of the faces of the square.

Fig. 781. represents one of these horizontal spindles. *n* is an eyelet through which

776



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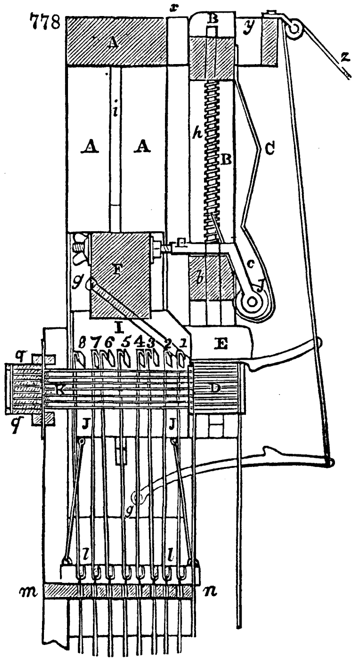

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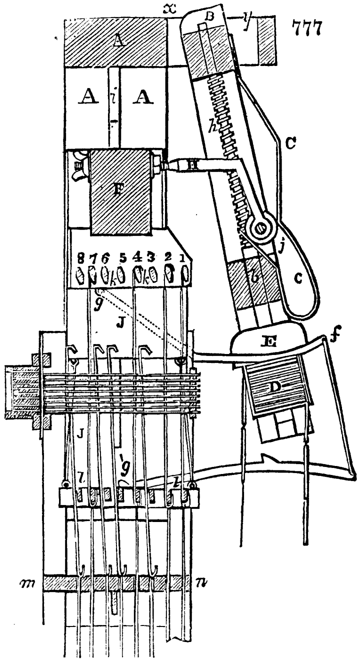
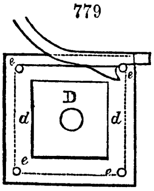


the corresponding vertical skewer passes. *o* another elongated eyelet, through which a small fixed spindle passes to serve as a guide, but which does not hinder it from moving lengthwise, within the limits of the length of the eyelet. *p*, small spiral springs placed in each hole of the case *q q*, *fig.* 780. They serve the purpose of bringing back to its primitive position every corresponding needle, as soon as it ceases to press upon it.

779



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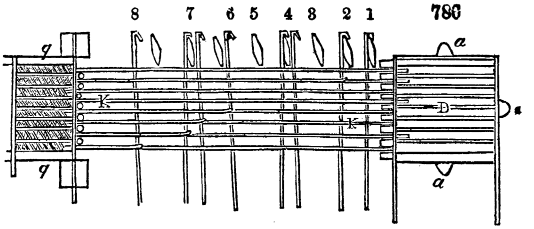

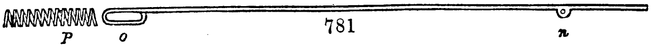

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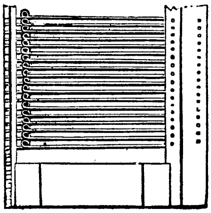
Fig. 782. represents the plan of the upper row of horizontal needles. *Fig.* 783. is a fragment of the endless chain, formed with perforated cards, which are made to circulate or travel by the rotation of the shaft D. In this movement, each of the perforated cards, whose position, form, and number, are determined by the operation of tying-up of the warp, comes to be applied in succession against the four faces of the square axis or drum, leaving open the corresponding holes, and covering those upon the face of the axis, which have no corresponding holes upon the card.

782



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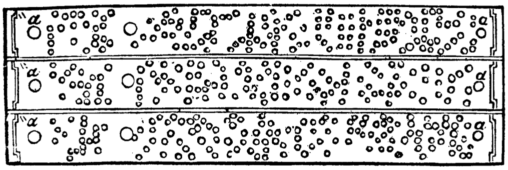


Now let us suppose that the *press* B is let down into the vertical position shown in *fig.* 778; then the card applied against the left face of the axis, leaves at rest or untouched the whole of the horizontal spindles (skewers), whose ends correspond to these holes, but pushes back those which are opposite to the unpierced part of the card; thereby the corresponding upright skewers, 3, 5, 6, and 8, for example, pushed out of the perpendicular, unhook themselves from above the bars of the claw, and remain in their place, when this claw comes to be raised by means of the lever G; and the skewers 1, 2, 4, and 7, which have remained hooked on, are raised along with the warp threads attached to them. Then by the passage across of a shot of the color, as well as a shot of the common weft, and a stroke of the lay after shedding the warp and lowering the press B, an element or point in the pattern is completed.

The following card, brought round by a quarter revolution of the axis, finds all the needles in their first position, and as it is necessarily perforated differently from the preceding card, it will lift another series of warp threads; and thus in succession for all the other cards, which compose a complete system of a figured pattern.

This machine, complicated in appearance, and which requires some pains to be understood, acts however in a very simple manner. Its whole play is dependant upon the movement of the lever G, which the weaver himself causes to rise and fall, by means of a peculiar pedal; so that without the aid of any person, after the piece is properly read in and mounted, he can execute the most complex patterns, as easily as he could weave plain goods; only attending to the order of his weft yarns, when these happen to be of different colors.

If some warp yarns should happen to break without the weaver observing them, or should he mistake his colored shuttle yarns, which would so far disfigure the pattern, he must undo his work. For this purpose, he makes use of the lower hooked lever *f*, whose purpose is to make the chain of the card go backwards, while working the loom as usual, withdrawing at each stroke the shot both of the ground and of the figure. The weaver is the more subject to make mistakes, as the figured side of the web is downwards, and it is only with the aid of a bit of looking-glass that he takes a peep of his work from time to time. The upper surface exhibits merely loose threads in different points, according as the pattern requires them to lie upon the one side or the other.

Thus it must be evident, that such a number of paste-boards are to be provided and mounted as equal the number of throws of the shuttle between the beginning and end of any figure or design which is to be woven; the piercing of each paste-board individually, will depend upon the arrangement of the lifting rods, and their connexion with the warp, which is according to the design and option of the workman; great care must be taken that the holes come exactly opposite to the ends of the needles; for this purpose two large holes are made at the ends of the paste-boards, which fall upon conical points, by which means they are made to register correctly.

It will be hence seen, that, according to the length of the figure, so must be the number of paste-boards, which may be readily displaced so as to remount and produce the figure in a few minutes, or remove it, or replace it, or preserve the figure for future use. The machine, of course, will be understood to consist of many sets of the lifting rods and needles, shown in the diagram, as will be perceived by observing the disposition of the holes in the paste-board; those holes, in order that they may be accurately distributed, are to be pierced from a gauge, so that not the slightest variation shall take place.

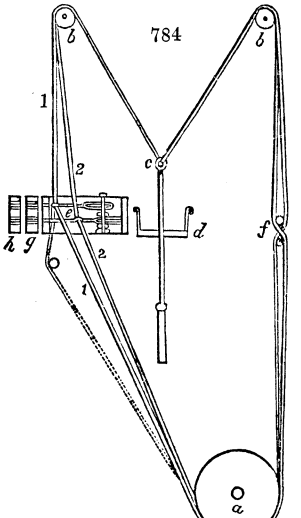
To form these card-slips, an ingenious apparatus is employed, by which the proper steel punches required for the piercing of each distinct card, are placed in their relative situations preparatory to the operation of piercing, and also by its means a card may be punched with any number of holes at one operation. This disposition of the punches is effected by means of rods connected to cords disposed in a frame, in the nature of a false simple, on which the pattern of the work to be performed is first read in.

These improved pierced cards, slips, or paste-boards, apply to a weaving apparatus, which is so arranged that a figure to be wrought can be extended to any distance along the loom, and by that means the loom is rendered capable of producing broad figured works; having the long lever G placed in such a situation that it affords power to the foot of the weaver, and by this means enables him to draw the heaviest morintures and figured works, without the assistance of a draw-boy.

The machinery for arranging the punches, consists of a frame with four upright standards and cross-pieces, which contains a series of endless cords passing under a wooden roller at bottom, and over pulleys at the top. These pulleys are mounted on axles in two frames, placed obliquely over the top of the standard frame, which pulley frames constitute the table commonly used by weavers.

In order better to explain these endless cords, *fig.* 784 represents a single endless cord 1, 1, which is here shown in operation, and part of another endless cord 2, 2, shown stationary. There must be as many endless cords in this frame as needles in the weaving-loom. *a* is the wooden cylinder, revolving upon its axis at the lower part of the standards; *b b*, the two pulleys of the pulley-frames above, over which the individual endless cord passes; *c* is a small traverse ring. To each of these rings a weight is suspended by a single thread, for the purpose of giving tension to the endless cord. *d* is a board resembling a common comber-bar, which is supported by the cross-bars of the standard frame, and is pierced with holes, in situation and number, corresponding with the perpendicular threads that pass through them; which board keeps the threads distinct from each other.

784



At *e*, the endless cord passes through the eyes of wires resembling needles, which are contained in a wooden box placed in front of the machine, and shown in this figure in section only. These wires are called the *punch-projectors;* they are guided and supported by horizontal rods and vertical pins, the latter of which pass through loops formed at the hinder part of the respective wires. At *f* are two horizontal rods extending the whole width of the machine, for the purpose of producing the cross in the cords; g is a thick brass plate, extending along in front of the machine, and lying close to the box which holds the *punch-projectors;* this plate g, shown also in section, is called the *punch-holder;* it contains the same number of apertures as there are punch-projectors, and disposed so as to correspond with each other. In each of these apertures, there is a punch for the purpose of piercing the cards, slips, or pasteboards with holes; *h* is a thick steel plate of the same size as g, and shown likewise in section, corresponding also in its number of apertures, and their disposition, with the punch-projectors and the punch-holder. This plate *h*, is called the *punch-receiver*.

The object of this machine is to transfer such of the punches as may be required for piercing any individual card from the punch-holder g, into the punch-receiver *h;* when they will be properly situated, and ready for piercing the individual card or slip, with such holes as have been read in upon the machine, and are required for permitting the warp threads to be withdrawn in the loom, when this card is brought against the ends of the needles. The process of transferring the patterns to the punches will be effected in the following manner.

The pattern is to be read in, according to the ordinary mode, as in a false simple, upon the endless cords below the rods *f*, and passed under the revolving wooden cylinder *a*, to a sufficient height for a person in front of the machine to reach conveniently. He there takes the upper threads of the pattern, called the *beard*, and draws them forward so as to introduce a stick behind the cords thus advanced, as shown by dots, for the purpose of keeping them separate from the cords which are not intended to be operated upon. All the punch-projectors which are connected with the cords brought forward, will be thus made to pass through the corresponding apertures of the punch-holder g, and by this means will project the punches out of these apertures, into corresponding apertures of the punch-receiver *h*. The punches will now be properly arranged for piercing the required holes on a card or slip, which is to be effected in the following manner.

Remove the punch-receivers from the front of the machine; and having placed one of the slips of card or pasteboard between the two folding plates of metal, completely pierced with holes corresponding to the needles of the loom, lay the punch-receiver upon those perforated plates; to which it must be made to fit by mortises and blocks, the cutting parts of the punches being downwards. Upon the back of the punch-receiver is then to be placed a plate or block, studded with perpendicular pins corresponding to the above described holes, into which the pins will fall. The plates and the blocks thus laid together, are to be placed under a press, by which means the pins of the block will be made to pass through the apertures of the punch-receiver; and wherever the punch has been deposited in the receiver by the above process, the said punches will be forced through the slip of pasteboard, and pierced with such holes as are required for producing the figured design in the loom.

Each card being thus pierced, the punch receiver is returned to its place in front of the machine, and all the punches forced back again into the apertures of the punch holder as at first. The next set of cords is now drawn forward by the next *beard*, as above described, which sends out the *punch-projectors* as before, and disposes the punches in the punch-receiver, ready for the operation of piercing the next card. The process being thus repeated, the whole pattern is, by a number of operations, transferred to the punches, and afterwards to the cards or slips, as above described.

JADE, axe-stone (*Nephrite*, *Ceraunite*, Fr.), is a mineral commonly of a greenish color, compact, and of a fatty lustre. Spec. Grav. 2·95; scratches glass, is very tough; fuses into a white enamel. Its constituents are, silica, 50·5; alumina, 10; magnesia, 31; oxyde of iron, 5·50; oxyde of chrome, 0·05; water, 2·75. It comes from China, is used among rude nations for making hatchets; and is susceptible of being cut into any form.

JAPANNING, is a kind of varnishing or lackering, practised with excellence by the Japanese, whence the name. See VARNISH.

JASPER (*Jaspe calcedoine*, Fr.; *Jaspis*, Germ.) is a sub species of calcedony quartz, of which there are five varieties. 1. The Egyptian red and brown, with ring or tendril-shaped delineations. 2. Striped jasper. 3. Porcelain jasper. 4. Common jasper. 5. Agate jasper. The prettiest specimens are cut for seals, and for the inferior kinds of jewellery ornaments. See LAPIDARY.

ICE-HOUSE; (*Glacière*, Fr.; *Eishaus*, Germ.) Under the article FREEZING I have enumerated the different artificial methods of producing cold.* But for the uses of common life, in these climates, the most economical and convenient means of refrigeration in hot weather may be procured by laying up a store of ice in winter, in such circumstances as will preserve it solid during summer.

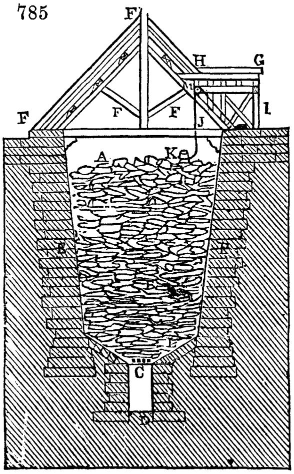
An ice-house should not be regarded as an object of mere luxury, for pleasing the palates of gourmands with iced creams and orgeats. In the southern countries of Europe it is considered among people in easy circumstances as an indispensable appendage to a country mansion. During the Dog-days, especially at those periods and in those districts where the *sirocco* blows, a lassitude and torpor of mind and body supervene, with indigestion or total loss of appetite, and sometimes dysenteries, which are obviously occasioned by the excessive heat, and are to be prevented or counteracted chiefly by the use of cold beverages. By giving tone to the stomach, iced drinks immediately restore the functions of the nervous and muscular systems when they are languid; while they enable persons in health to endure without much inconvenience an atmosphere so close and sultry as would be intolerable without this remedy. Ice-houses, moreover, afford to country gentlemen a great advantage in enabling them to preserve their fish, butcher meat, dead poultry, and game, which would otherwise, in particular states of the weather, immediately spoil. Considering at how little expense and trouble an ice-house can be constructed, it is surprising that any respectable habitation in the country should not have one attached to it. The simplest and most scientific form is a double cone, that is, two cones joined base to base; the one being of stones or brickwork, sunk under ground with its apex at the bottom, into which the ice is rammed; the other being a conical roof of carpentry covered with thatch, and pointed at top. The entrance should be placed always on the north side; it should consist of a corridor or porch with double doors, and be screened from the sunbeams by a small shrubbery. Such are, in general, the principles upon which an ice-house should be formed; but they will be better understood by the following explanation and figure.

A dry sandy soil should be selected, and, if possible, a spot sheltered by a cliff or other natural barrier from the direct rays of the sun. Here a cavity is to be dug about 16 feet in diameter, terminating below like the point of a sugar loaf. Its ordinary depth, for a moderate family, may be about 24 feet; but the larger its dimensions are, the longer will it preserve the ice, provided it be filled. In digging, the workman should slope the ground progressively towards the axis of the cone, to prevent the earth falling in. This conical slope should be faced with brick or stone work about one foot thick, and jointed with Roman cement so as to be air and water tight. A well is to be excavated at the bottom two feet wide and four deep, covered at top with an iron grating for supporting the ice, and letting the water drain away.

The upper cone may likewise be built of brickwork, and covered with thatch; such a roof would prove the most durable. This is the construction shown in *fig.* 785. What ever kind of roof be preferred, there must be left in it an oblong passage into the interior. This porch should face the north, and be at least 8 feet long by 2½ feet wide; and perfectly closed by a well-fitted door at each end. All round the bottom of this conical cover, a gutter should be placed to carry off the rain to a distance from the ice-house, and prevent the circumjacent ground from getting soaked with moisture.

Fig. 785 shows the section of a well-constructed ice-house. Under the ice-chamber A the ice is rammed into the space B. C is the grate of the drain-sink D. The portion E E is built in brick or stone; the base L of the ice-chamber slopes inwards towards the centre at C. The upper part of the brickwork E E is a little way below the level of the ground. The wooden frame work F F F F forms the roof, and is covered with thick thatch. G H is the wooden work of the door I. At K the bucket is seen for lifting up a charge of ice, by means of the cord J passing over the pulley M, which enables the servant to raise it easily.

785



The icehouse should have no window to admit light; but be, so to speak, hermetically sealed in every point, except at its cess-pool, which may terminate in a water trap to prevent circulation of air.

A clear day should be selected for charging the icehouse; but before beginning to fill, a quantity of long dry straw should be laid on the bottom crosswise; and as the ice is progressively introduced, straw is to be spread against the conical sides, to prevent the ice from coming into contact with the brick or stone work. The more firmly compacted the ice is, the better does it keep; with which view it should be broken into pieces with mallets before being thrown in. No layers of straw should be stratified among the ice, for they would make its body porous. Some persons recommend to pour in a little water with the successive layers of ice, in order to fill up its small crevices, and convert the whole into one mass.

Over the top layer a thick bed of straw should be spread, which is to be covered with boards surmounted with heavy stones, to close up the interstices in the straw. The inner and outer doors should never be opened at once; but the one should always be shut before the other is opened.

Dry snow well rammed keeps equally well with hard ice, if care be taken to leave no cavities in the mass, and to secure its compactness by sprinkling a little water upon the successive charges.

To facilitate the extraction of the ice, a ladder is set up against its sloping wall at one side of the door, and left there during the season.

ICE PRODUCING MACHINE. It is well known that by the rapid condensation of air or other elastic fluid, so much heat may be evolved as to ignite tinder, &c. It appears from a communication in the *Mechanics' Magazine* of February, 1851, that Dr. Gorrie a physician in New Orleans, has on this principle constructed an apparatus for producing so much cold as to freeze water, by exposure to the condensed air in the act of its subsequent expansion. Gay Lussac, many years ago, made use of a jet of condensed air to refrigerate any body such as a glass globe filled with water, upon which the expanding air was allowed to play, and he even caused water contained in the globe to freeze. Now the American process is quite identical with that of the French chemist, but on a vastly enlarged scale, for he employs the power of a steam engine acting on a pump 8 inches in diameter, with a 16 inches stroke, to condense the air into one third its volume, into a vessel, where it is cooled by water. A pump is made to throw in a jet of cold water at the same time to quicken the refrigeration. It is said that in this way a block of ice of 60 lbs. was formed; a circumstance which appears to me quite incredible. In fact, the whole statement has a most apocryphal air, and I do not believe that any such result could have been produced, as the reporter says, by the labour of two men at a couple of pumps in alternate action.

The inventor's object at first was to ventilate and cool the atmosphere of sick rooms, where febrile patients lay. "This case is one among the many examples of a useful scientific invention remaining long dormant or sterile." The hydrostatic paradox of Archimedes is a parallel instance, in reference to Bramah's press.

ICE BY THE RED-HOT PROCESS. One of the most singularly beautiful experiments perhaps ever devised, has been recently published by M. Prevostaire, illustrative of the repellent power of heat radiating from bodies at a high temperature, and of the rapid abstraction of heat, produced by evaporation, or generally by such a change of condition as largely increases the volume of any body. The experiment is simply this:—A platina crucible is made and maintained red-hot over a large spirit lamp. Some sulphurous acid is poured into it from a pipette. This acid, though at common temperatures one of the most volatile of known bodies, possesses the singular property of remaining fixed in the red-hot crucible and not a drop of it evaporates: in fact, it is not in contact with the crucible, but has an atmosphere of its own interposed. A few drops of common water are now added to the sulphurous acid in the red-hot crucible. The diluted acid gets into immediate contact with the heated metal, instantly flashes off into sulphurous acid vapour, and such is the rapidity and energy of the evaporation that the water remains behind, and is found frozen into a lump of ice in the red-hot crucible, from which, seizing the moment before it again melts, it may be thrown out before the eyes of the astonished observer.

JELLY, VEGETABLE, of ripe currants and other berries, is a compound of mucilage and acid, which loses its power of gelatinizing by prolonged ebullition.

JELLY, ANIMAL; see GELATINE, GLUE and ISINGLASS.

JET; (*Jaiet* or *jais*, Fr.) a species of pitch coal, or glance-coal, which, being found abundantly in a beautiful compact form, in the valley of Hers, arrondissement of Pamiers, department of the Arriège, has been worked up extensively there, from time immemorial, into a multitude of ornamental articles. With this black lignate, buttons, crosses, rosaries, necklaces, ear-drops, bracelets, waist-buckels, &c., are made, which were at one time much worn by ladies for mourning dresses. The greater number of these ornaments are fashioned upon grindstones which turn in a horizontal direction, and are kept continually wet; others are turned at the lathe, or shaped by files.

About 40 years ago this manufacture employed from 1000 to 1200 operatives; at present it gives bread to only 60. This falling off may be ascribed to the successful imitation of the jet articles by those of black glass, which are equally beautiful, and not nearly so apt to lose their polish by use.

JET PUMP. The purpose for which this instrument is designed, is to clear the water out of the pits of submerged water-wheels, when access to them is required for inspection or repairs. For this special purpose it is likely to prove very useful; though at the same time, there are very few other cases in which it could not be employed with advantage. The action of the jet pump depends on two principles. One of these is the same as that of steam blast used in locomotive engines, and in the ventilation of mines. The other is one which was known to the ancient Romans, and was used sometimes by them for drawing off more water from the public pipes than they paid for. The jet pump was first tried at the mill of Messrs. Herdman & Co., Belfast, when it was found most successful.

ILLUMINATION, COST OF. The production, diffusion, and economy of light, are subjects of the highest interest both to men of science and men of the world; leading the former to contemplate many of the most beautiful phenomena of Physics and Chemistry, while they provide the latter with the artificial illumination so indispensable to the business and pleasures of modern society. The great cost of light from wax, spermaceti, and even stearic candles, as also the nuisance of the light from tallow ones, have led to the invention of an endless variety of lamps, of which the best hitherto known is undoubtedly the mechanical or Carcel lamp, so generally used by the opulent families in Paris. In this lamp the oil is raised through tubes by clock-work, so as continually to overflow at the bottom of the burning wick; thus keeping it thoroughly soaked, while the excess of the oil drops back into the cistern below. I have possessed for several years an excellent lamp of this description, which performs most satisfactorily; but it can hardly be trusted in the hands of a servant; and when it gets at all deranged, it must be sent to its constructor in Paris to be repaired. The light of this lamp, when furnished with an appropriate tall glass chimney, is very brilliant, though not perfectly uniform; since it fluctuates a little, but always perceptibly to a nice observer, with the alternating action of the pump-work; becoming dimmer after every successive jet of oil, and brighter just before its return. The flame, moreover, always flickers more or less, owing to the powerful draught, and rectangular reverberatory shoulder of the chimney. The mechanical lamp is, however, remarkable for continuing to burn, not only with unabated but with increasing splendour for seven or eight hours; the vivacity of the combustion increasing evidently with the increased temperature and fluency of the oil, which, by its ceaseless circulation through the ignited wick, gets eventually pretty warm. In the comparative experiments made upon different lights by the Parisian philosophers, the mechanical lamp is commonly taken as the standard. I do not think it entitled to this pre-eminence: for it may be made to emit very different quantities of light, according to differences in the nature and supply of the oil, as well as variations in the form and position of the chimney. Besides, such lamps are too rare in this country to be selected as standards of illumination.

After comparing lights of many kinds, I find every reason to conclude that a large wax candle of three to the pound, either long or short, that is, either 12 or 15 inches in length, as manufactured by one of the great wax-chandlers of London, and furnished with a wick containing 27 or 28 threads of the best Turkey cotton, is capable of furnishing a most uniform, or nearly invariable standard of illumination. Its affords one tenth of the light emitted by one of the Argand lamps of the Trinity house, and one eleventh of the light of my mechanical lamp, when each lamp is made to burn with its maximum flame, short of smoking.

The great obstacle to the combustion of lamps, lies in the viscidity, and consequent sluggish supply of oil, to the wicks; an obstacle nearly insuperable with lamps of the common construction during the winter months. The relative viscidity, or relative fluency of different liquids at the same temperature, and of the same liquid at different temperatures, has not, I believe, been hitherto made the subject of accurate researches. I was, therefore, induced to make the following experiments with this view.

Into a hemispherical cup of platinum, resting on the ring of a chemical stand, I introduced 2,000 water-grain measures of the liquid whose viscidity was to be measured, and ran it off through a glass syphon, $\frac{1}{8}$ of an inch in the bore, having the outer leg $3\frac{1}{4}$ inches, and the inner leg 3 inches long. The time of efflux became the measure of the viscidity; and of two liquids, if the specific gravity, and consequent pressure upon the syphon, were the same, that time would indicate exactly the relative viscidity of the two liquids. Thus, oil of turpentine and sperm oil have each very nearly the same density; the former being, as sold in the shops, =0·876, and the latter from 0·876 to 0·880, when pure and genuine. Now I found that 2,000 grain-measures of oil of turpentine ran off through the small syphon in 95 seconds, while that quantity of sperm oil took 2,700 seconds, being in the ratio of 1 to $28\frac{1}{2}$; so that the fluency of oil of turpentine is $28\frac{1}{2}$ times greater than that of sperm oil. Pyroxilic spirit, commonly called naphtha, and alcohol, each of specific gravity 0·825, were found to run off respectively in 80 and 120 seconds; showing that the former was 50 per cent. more fluent than the latter. Sperm oil, when heated to 265 Fahr., runs off in 300 seconds, or one ninth of the time it took when at the temperature of 64°. Southern whale oil, having a greater density than the sperm oil, would flow off faster were it not more viscid.

2,000 grain-measures of water at 60° run off through the said syphon in 75 seconds, but when heated to 180°, they run off in 61

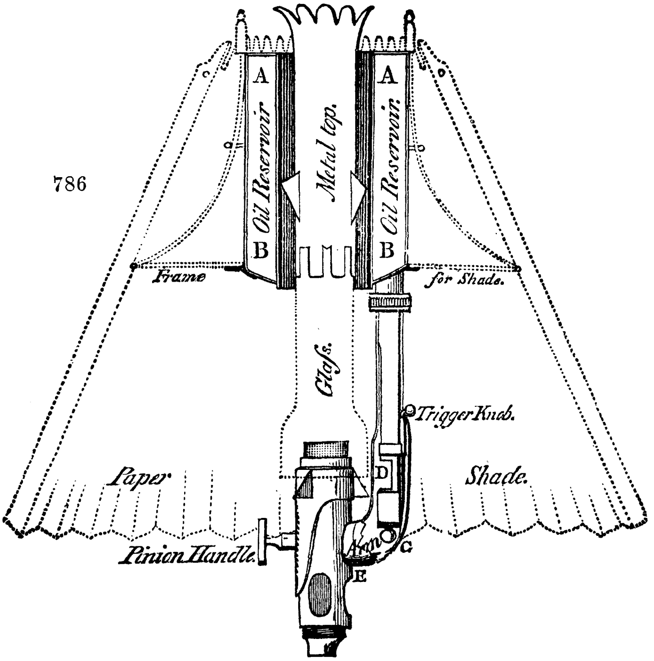
Concentrated sulphuric acid, though possessing the great density of 1·840, yet flows off very slowly at 64°, on account of its viscidity; whence its name of oil of vitriol. 2,000 grain-measures of it took 660 seconds to discharge.

Mr. Samuel Parker, long advantageously known to the public for his sinumbral and pneumatic fountain lamps, as well as other inventions subservient to domestic comfort, having obtained a patent for a new lamp, in which the oil is heated by a very simple contrivance, in the cistern, to any desired degree, before arriving at the wick, I instituted an extensive series of experiments to determine its value in the production of light, and consumption of oil, compared to the value of other lamps, as well as candles, in these respects.

In *fig.* 786, A, A, B, B, is a section of the cylinder which constitutes the cistern; the oil being contained between the inner and outer cylinders, and receiving heat from the flame of the lamp which passes up through the inner cylinder, and is reverberated more or less against its sides by the top of the metal chimney, being notched and bent back. D is a slide-valve which is opened to allow the oil to descend to the wick, and is shut when the cistern is to be separated from the pipe of supply, at E, for the purpose of recharging it with oil. The flame is modified, not by raising or lowering the wick, as in common lamps, but by raising or lowering the bell-mouthed glass chimney which rests at its bottom on three points, and is moved by means of the rack-work mechanism F. The concentric cylindric space A, A, and B, B, contains a pint imperial, and should be made entirely full before lighting the lamp; so as to leave no air in the cistern, which, by its expansion with the heat, would inevitably cause an overflow of the oil.

The following arrangement was adopted in these experiments for determining the relative illumination of the different lights. Having trimmed, with every precaution, my French mechanical lamp, and charged it with pure sperm oil, I placed it upon an oblong table, at a distance of 10 feet from a wall, on which a white sheet of paper was stuck. One of Mr. Parker's hot-oil lamps, charged with a quantity of the same oil, was placed upon the same table; and each being made to burn with its maximum brilliancy, short of smoking, the relative illumination of the two lamps was determined by the well-known method of the comparison of shadows; a wire a few inches long, and of the thickness of a crow-quill, being found suitable for enabling the eye to estimate very nicely the shade of the intercepted light. It was observed in numerous trials, both by my own eyes and those of others, that when one of the lamps was shifted half an inch nearer to or further from the paper screen, it caused a perceptible difference in the tint of the shadow. Professor Wheatstone kindly enabled me to verify the precision of the above method of shadows, by employing, in some of the experiments, a photometer of his own invention, in which the relative brightness of the two lights was determined by the relative brightness of the opposite sides of a revolving silvered ball, illuminated by them.

786



1. The mechanical lamp was furnished with a glass chimney 1·5 inches in diameter at the base, and 1·2 at top; the wide bottom part was 1·8 inches long, and the narrow upper part 8 inches. When placed at a distance of 10 feet from the wall its light there may be estimated as the square of this number, or 100. In the first series of experiments, when burning with its maximum flame, with occasioned flickerings of smoke, it emitted a light equal to that of 11 wax candles, and consumed 912 grains of oil per hour. The sperm oil was quite pure, having a specific gravity of 0·874 compared to

water at 1,000. In a subsequent series of experiments, when its light was less flickering, and equal only to that of 10 wax candles, it consumed only 815 grains, or 0·1164 of a lb. per hour. If we multiply this number into the price of the oil (8*s.* per gallon) per lb. 11*d.*, the product 1·2804*d.* will represent the relative cost of this illumination, estimated at 100.

2. The hot-oil lamp burns with a much steadier flame than the mechanical, which must be ascribed in no small degree to the rounded slope of the bell-mouthed glass chimney, whereby the air is brought progressively closer and closer into contact with the outer surface of the flame, without being furiously dashed against it, as it is by the rectangular shoulder of the common contracted chimney. When charged with sperm oil, and made to burn with its maximum flame, this lamp required to be placed one foot further from the screen than the mechanical lamp, in order that its shadow should have the same depth of tint. Hence, its relative illumination was, in that case, as the square of 11 to the square of 10; or as 121 to 100. Yet its consumption of oil was only 696 grains, or somewhat less than 0·1 of a pound per hour. Had its light been reduced to 100, it would have consumed only 576 grains per hour, or 0·82 of a pound. If we multiply this number by 11*d.*, the product 0·902*d.* will represent the relative cost of 100 of this illumination.

3. The hot-oil lamp being charged with the southern whale oil, of specific gravity 0·926, at 2*s.* 6*d.* per gallon, or 3¼*d.* per lb., when burning with its maximum flame, required to be placed 9 feet and 1 inch from the screen to drop the same tint of shadow upon it as the flames of the other two lamps did at 10 and 11 feet with the sperm oil. The square of 9 feet and 1 inch = 82 is the relative illumination of the hot-oil lamp with the southern whale oil. It consumed 780 grains, or 0·111 of a pound per hour; but had it given 100 of light it would have consumed 911 grains, or 0·130 of a pound, which number being multiplied by its price 3¾*d.*, the product 0·4875*d.* will represent the relative cost of 100 of this light.

4. A hot-oil lamp charged with olive oil of specific gravity 0·914, at 5*s.* 6*d.* per gallon, or 7½*d.* per lb. when burning with its maximum flame, required to be placed at 9 feet 6 inches, to obtain the standard tint of shadow upon the screen. It consumed 760 grains per hour. The square of 9½ feet is 90¼, which is the relative intensity of the light of this lamp. Had it emitted a light = 100, it would have consumed 840 grains, or 0·12 of a pound per hour—which number multiplied by the price per pound, gives the product 0·9*d.* as the relative cost of 100 of this light.

5. A hot-oil lamp charged with Price and Co.'s cocoa-nut oil (oleine), of specific gravity 0·925, at 4*s.* 6*d.* per gallon, or 5¾*d.* per lb., had to be placed 9 feet from the screen, and consumed 1,035 grains per hour. Had its light been 100 instead of 81 (9^2), the consumption would have been 1,277 grains, or 0·182 of a pound per hour! which number multiplied by its price per pound, the product 1·031*d.* will represent the cost of 100 of this illumination.

6. In comparing the common French annular lamp in general use with the mechanical lamp, it was found to give about one half the light, and to consume two thirds of the oil of the mechanical lamp.

7. Wax candles from some of the most eminent wax-chandlers of the metropolis were next subjected to experiment; and it is very remarkable that, whether they were threes, fours, or sixes in the pound, each afforded very nearly the same quantity of light, for each required to be placed at a distance of three feet from the screen to afford a shadow of the same tint as that dropped from the mechanical lamp, estimated at 100. The consumption of a genuine wax candle, in still air, is upon an average of many experiments, 125 grains per hour, but as it affords only 1 11th of the light of the mechanical lamp, 11 times 125 = 1,375 grains, or 0·1064 of a pound is the quantity that would need to be consumed to produce a light equal to that of the said lamp. If we multiply that number by the price of the candles per lb. = 30*d.* the product = 5·892*d.* is the cost of 100 of illumination by wax. A wax candle, three in the pound (short), is one inch in diameter, 12 inches in length, and contains 27 or 28 threads, each about 1 10th of an inch in diameter. But the quality of the wick depends upon the capillarity of the cotton fibrils, which is said to be greatest in the Turkey cotton, and hence the wicks for the best wax candles are always made with cotton yarn imported from the Levant. A wax candle, three in the pound (long), is ⅞ of an inch in diameter, 15 inches long, and has 26 threads in its wick. A wax candle, six to the pound, is 9 inches long, 4 5ths of an inch in diameter, and has 22 threads in its wick. The light of this candle may be reckoned to be, at most, about 1 11th less than that of the threes in the pound. A well-made short three burns with surprising regularity in still air, being at the rate of an inch in an hour and a half, so that the whole candle will last 18 hours. A long three will last as long, and a six about 9½ hours. Specific gravity of wax = 0·960.

8. A spermaceti candle, three in the pound, is 9 10ths of an inch in diameter, 15 inches long, and has a plaited wick, instead of the parallel threads of a wax candle. The

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same candles four in the pound, are 8 10ths of an inch in diameter, and 13½ inches long Each gives very nearly the same quantity of light as the corresponding wax candles: viz., 1 11th of the light of the above mechanical lamp, and consumes 142 grains per hour. Multiplying the last number by 11, the product, 1,562 grains = 0·223 of a pound would be the consumption of spermaceti requisite to give 100 of illumination. Multiplying the last number by 24*d.*, the price of the candles per pound, the product 5·352*d.* is the relative cost of 100 of this illumination.

9. *Stearic acid* candles, commonly called German wax, consume 168·5 grains, or 0·024 of a pound per hour, when emitting the same light as the standard wax candle. Multiplying the latter number by 11, and by 16*d.* (the price of the candles per pound), the product 4·224*d.* will represent the relative cost of 100 of this illumination.

10. Tallow candles: moulds, short threes, 1 inch in diameter, and 12½ in length; do. long threes, 9 10ths of an inch in diameter, and 15 in length; do., long fours, 8 10ths of an inch in diameter, and 13¾ in length. Each of these candles burns with a most uncertain light, which varies from 1 12th to 1 16th of the light of the mechanical lamp—the average may be taken at 1 14th. The threes consume each 144 grains, or 0·2 of a pound, per hour; which number, multiplied by 14, and by 9*d.* (the price per pound), gives the product 2·52*d.* for the relative cost of 100 of this illumination.

11. Palmer's spreading wick candles. Distance from the screen 3 feet 4 inches, with a shadow equal to the standard. Consumption of tallow per hour 232·5 grains, or 0·0332 of a pound. The square of 3 feet 4 inches = 11·9 is the relative illumination of this candle = 11·9 : : 0·3332 : : 100 : 0·28 × 10*d.* = 11·9 is the relative cost of this illumination.

12. Cocoa-nut stearine candles consumed each 168 grains per hour, and emitted a light equal to 1 16th of the standard flame. Multiplying 168 by 16, the product 30·88 grains, or 0·441 of a pound, is the quantity which would be consumed per hour to afford a light equal to 100. And 0·441 multiplied by 10*d.*, the price per pound, gives the product 4·441*d.* as the cost of 100 of this illumination per hour.

A gas argand London lamp, of 12 holes in a circle of ¾ of an inch in diameter, with a flame 3 inches long, afforded a light = 78½ compared to the mechanical lamp: and estimating the light of the said mechanical lamp as before, at 100, that of the hot-oil lamp is 121, and that of the above gas flame of 78·57, or in round numbers 80, *and the common French lamp in general use* 50.

Collecting the preceding results, we shall have the following tabular view of the cost per hour of an illumination equal to that of the mechanical lamp, reckoned 100, or that of eleven wax candles, three to the pound.

Table of Cost per Hour of One Hundred of Illumination.

		Pence.		Pence
1.	Parker's hot-oil lamp, with southern whale oil	0·4875	or about	½*d.*
2.	Mechanical or Carcel lamp, with sperm oil	1·2804		1¼
3.	Parker's hot-oil lamp, with sperm oil	0·902		1
4.	Ditto ditto common olive oil	0·900		1
5.	Ditto ditto cocoa-nut oleine or oil	1·031		1
6.	French lamp in general use, with sperm oil	1·7072		1¾
7.	Wax candles	5·892		6
8.	Spermaceti candles	5·352		5¼
9.	German wax (Stearic acid) ditto	4·224		4¼
10.	Palmer's spreading wick candles	2·800		2¾
11.	Tallow (mould) candles	2·520		2½
12.	Cocoa-nut stearine of Price and Co.	4·41		4½

Since the hot-oil lamp affords sufficient light for reading, writing, sewing, &c., with one fifth of its maximum flame, it will burn at that rate for 10 hours at the cost of about ONE PENNY, and it is hence well entitled to the inventor's designation, "The Economic."

Sir D. Brewster, in his examination lately before the committee of the house of commons on lighting the house, stated, that the French light-house lamp of Fresnel emitted a light equal to that of forty argand flames; whereas, according to other accounts, it gave much less light. With the view of settling this point, before being examined by the said committee, I repaired to the Trinity house, and tried one of the two original Fresnel lamps, which had been deposited there by that eminent French engineer himself. This lamp consists of four concentric circular wicks, placed in one horizontal plane; the innermost wick being ⅞ of an inch in diameter, and the outermost 3½ inches. Being carefully trimmed, supplied with the best sperm oil, surmounted with its great glass chimney, burning with its maximum flame, and placed at a distance of 13 feet 3 inches from the screen, it let fall a shadow of the same tint as that let fal by the flame of my mechanical lamp, placed at a distance of 4 feet 6 inches from the screen. The squares of these two numbers are very nearly as 8¾ to 1 (175·5625 to 20·25); showing that the Fresnel lamp gives less than 9 times the light of my mechanical lamp, and about 9·6 times the light of one of the Trinity house argand lamps. The Fresnel lamp is exceedingly troublesome to manage, from the great intensity of its heat, and the frequent fractures of its chimneys—two having been broken in the course of my experiments at the Trinity house.

Mr. Goldsworthy Gurney, the ingenious inventor of the new light-house lamp, in which a stream of oxygen gas is sent up through a small tube within the burning circular wick of a small argand lamp, having politely sent two of his lamps to my house, along with a bag of oxygen gas, I made the following experiments, to ascertain their illuminating powers compared to those of the mechanical lamp and wax candles.

His larger lamp has a wick ⅝ of an inch in diameter, but emits an oxygen flame of only ⅜ of an inch. The flame is so much whiter than that of the best lamp or candle that it becomes difficult to determine, with ultimate precision, the comparative depths of the shadows let fall by them. The mean of several trials showed that the above *Bude*-light (as Mr. Gurney calls it, from the name of his residence in Cornwall), has an illuminating power of from 28 to 30 wax candles. His smaller lamp has a flame ¼ of an inch in diameter, and a wick ½ of an inch. Its light is equal to that of from 18 to 20 wax candles.

The committee of the house of commons on lighting it, having asked me what was the relative vitiation of air by the breathing of men and the burning of candles, I gave the following answer:—

Wax contains 81·75 parts of carbon in 100, which generate by combustion 300 parts of carbonic acid gas. Now, since 125 grains of wax constitute the average consumption of a candle per hour, these will generate 375 grains of carbonic acid; equivalent in volume to 800 cubic inches of gas. According to the most exact experiments on respiration, a man of ordinary size discharges from his lungs 1,632 cubic inches of carbonic acid gas per hour, which is very nearly the double of the quantity produced from the wax candle. Hence the combustion of two such candles vitiates the air much the same as the breathing of one man. A tallow candle, three or four in the pound, generates nearly the same quantity of carbonic acid as the wax candle; for though tallow contains only 79 per cent. of carbon, instead of 81.75, yet it consumes so much faster, as thereby to compensate fully for this difference.

When a tallow candle of 6 to the lb. is not snuffed, it loses in intensity, in 30 minutes, 80 hundredths; and in 39 minutes 86 hundredths, in which dim state it remains stationary, yet still consuming nearly the same proportion of tallow. A wax candle attains to its greatest intensity of light when its wick has reached the greatest length, and begins to bend out of the flame. The reason of this difference is, that only the lower part of the wick in the tallow candle is charged with the fat, so as to emit luminiferous vapor, while the upper part remains dry; whereas, in the wax candle, the combustible substance being less fusible and volatile, allows a greater length of the wick to be charged by capillary attraction, and of course to emit a longer train of light.

The following table contains, according to Péclet, the illuminating powers of different candles, and their consumption of material in an hour; the light emitted by a *Carcel* argand lamp, consuming 42 grammes (= 42 × 15½ grains) in an hour, being called 100:—

	Intensity of Light.	Consumption per Hour
Tallow Candles 6 in lb. - -	10·66	8·51
Stearine, or Pressed Tallow, 8 in lb. -	8·74	7·51
———— 5 in lb. -	7.50	7·42
Wax Candles, 5 in lb. - - -	13·61	8·71
Spermaceti ditto, 5 in lb. - -	14·40	8·92
Stearic Acid, commonly called Stearine, 5 in lb. - - - -	14·40	9·33

The subjoined table shows the economical ratios of the candles, where the second column gives the quantity of material in grammes which is requisite to produce as much light as the Carcel lamp:—

	Quality of Material.	Price per Kilogramme.	Cost of Light per Hour.
Tallow candle, 6 per lb. - - -	70·35	1 f. 40 c.	9·8 c.
————————, 8 per lb. - - -	65·92	1 f. 40 c.	12·0 c.
Pressed tallow, 5 per lb. - - -	98·93	2 f. 40 c.	23·7 c.
Wax candle, 5 per lb. - - - -	64·04	7 f. 60 c.	48·6 c.
Spermaceti ditto, 5 per lb. - - -	61·94	7 f. 60 c.	47·8 c.
Stearine, 5 per lb. - - - - -	65·24	6 f.	37·1 c.

These results may be compared with mine given above. A kilogramme, or 1000 grammes = 15,440 grains = 2¼ lbs. avoirdupois.

JINTA-WAN. A compound, elastic, water-repellent substance for manufacturing purposes is made by combining gutta percha with an elastic and water-repellent substance called "jinta-wan," recently imported for the first time from the East Indies, and which has never heretofore, to the best of my knowledge and belief, been used in the arts and manufactures of this country; or by combining gutta percha with "jinta-wan" and caoutchouc. The gutta percha which is intended to be combined in this way should, if necessary, be cleansed from impurities, and may if desired be previously prepared as heretofore described. The jinta-wan, or caoutchouc, should also be cleansed from its impurities, if any. Gutta percha and jinta-wan are combined by placing these two substances in the intended proportions (cut into pieces) in a masticator, such as is used for masticating caoutchouc, and then operate upon the two materials by that machine until they are intimately blended together. And the triple combination of gutta percha, jinta-wan, and caoutchouc are combined by means of a masticator, in the same manner. For the purpose of making these combinations, the proportions of the two, or of the three substances may be combined according to the quality which it is desired that the combined substance shall possess, employing a larger proportion of any one of the substances to be combined, when it is desired that the peculiar qualities of that substance shall predominate in the combined article. See Gutta Percha.

IMPERMEABLE, is the epithet given to any kind of textile fabric, rendered waterproof by one or other of the following substances:—

1. Linseed oil to which a drying quality has been communicated by boiling with litharge or sugar of lead, &c.
2. The same oil holding in solution a little caoutchouc.
3. A varnish made by dissolving caoutchouc in rectified petroleum or naphtha, applied between two surfaces of cloth, as described under Macintosh's patent. See Caoutchouc.
4. Vegetable or mineral pitch, applied hot with a brush, as in making tarpauling for covering goods in ships.
5. A solution of soap worked into cloth, and decomposed in it by the action of a solution of alum; whence results a mixture of acid fats and alumina, which insinuates itself among all the woolly filaments, fills their interstices, and prevents the passage of water.
6. A solution of glue or isinglass, introduced into a stuff, and then acted upon by a clear infusion of galls, whereby the fibres get impregnated with an insoluble, impermeable, pulverulent leather.
7. Plaster work is rendered impermeable by mixing artificial or natural asphaltum with it.

JEWELLERY, *Art of.* See Gem and Lapidary.

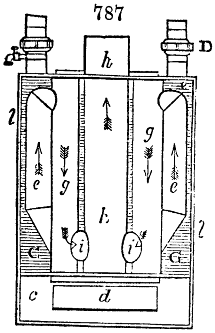
INCOMBUSTIBLE CLOTH; is a tissue of the fibrous mineral called amianthus or asbestos. This is too rare to form the object of any considerable manufacture. Cotton and linen cloth may be best rendered incapable of taking fire, or burning with flame, by being imbued with a solution of sal ammoniac.

INCUBATION, ARTIFICIAL. The Egyptians have from time immemorial been accustomed to hatch eggs by artificial warmth, without the aid of hens, in peculiar stoves, called *Mammals.* The inhabitants of the village Bermé still travel through the most distant provinces of Egypt at certain seasons of the year, with a portable furnace, heated by a lamp, and either hatch chickens for sale, or undertake to hatch the eggs belonging to the natives at a certain rate per dozen. M. de Reaumur published in France about a century ago, some ingenious observations upon this subject; but M. Bonnemain was the first person who studied with due attention all the circumstances of artificial incubation, and mounted the process successfully upon the commercial scale. So far back as 1777 he communicated to the Academy of Sciences an interesting fact, which he had noticed, upon the mechanism employed by chicks to break their shells; and for some time prior to the French revolution he furnished the Parisian market with excellent poultry at a period of the year when the farmers had ceased to supply it. His establishment was ruined at that disastrous era, and no other has ever since been constructed or conducted with similar care. As there can be no doubt however of the practicability and profitableness of the scheme, when judiciously managed, I shall insert a brief account of his ingenious arrangements. I had the pleasure of making the acquaintance of this amiable old man at my first visit to Paris, many years ago, and believe all his statements to be worthy of credit. Some imitations of his plans have been made in this country, but how far they have succeeded in an economical point of view, it is difficult to determine. His apparatus derives peculiar interest from the fact, that it was founded upon the principle of the circulation of hot water, by the intestine motion of its particles, in a returning series of connected pipes; a subject afterwards illustrated in the experimental researches of Count Rumford. It has of late years been introduced as a *novelty* into this country, and applied to warm the apartments of many public and private buildings. The following details will prove that the theory and practice of hot-water circulation were as perfectly understood by M. Bonnemain fifty years ago, as they are by any of our stove doctors at the present day. They were then publicly exhibited at his residence in Paris, and were afterwards communicated to the world at large in the interesting article of the *Dictionnaire Technologique*, entitled *Incubation Artificielle.*

The apparatus of M. Bonnemain consisted; 1. of a boiler, and pipes for the circulation of water; 2. of a regulator calculated to maintain an equable temperature; 3. of a stove-apartment, heated constantly to the degree best fitted for incubation, which he called the *hatching* pitch. He attached to one side a *poussinière* or chick-room, for cherishing the chickens during a few days after incubation.

The boiler is represented in vertical section and ground plan, in *figs.* 787 and 788. It is composed of a double cylinder of copper or cast iron *l*, *l*, having a grate *b* (see plan), an ash-pit at *d* (section). The water occupies the shaded space C, C. *h*, *g*, *g*, *e*, *e*, are five vertical flues, for conducting the burnt air and smoke, which first rise in the two exterior flues *e*, *e*, then descend in the two adjoining flues *g*, *g*, and finally re-mount through the passages *i*, *i*, in the central flue *h*. During this upwards and downwards circulation, as shown by the arrows in the section, the products of combustion are made to impart nearly the whole of their heat to the water by which they are surrounded. At the commencement some burning paper or wood shavings are inserted at the orifice *m*, to establish a draught in this circuitous chimney. The air is admitted into the ash-pit at the side, in regulated quantities, through a small, square door, moveable round a rod which runs horizontally along its middle line. This swing valve is acted upon by an expanding bar (see Heat-Regulator), which opens it more or less according to the temperature of the stove apartment in which the eggs are placed.

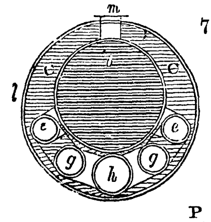
787



D is the upper orifice of the boiler, by which the hotter and consequently lighter particles of the water continually ascend, and are replaced by the cooled particles, which enter the boiler near its bottom, as shown in *fig.* 789. at R. Into further details relative to the boiler it is needless to enter; for though its form, as designed by M. Bonnemain, is excellent and most economical of heat for a charcoal fire, it would not suit one of pit-coal, on account of the obstruction to the pipes which would soon be occasioned by its soot.

In *fig.* 789. the boiler is shown at R, with the rod which regulates the air door of the ash-pit. D is a stopcock for modifying the opening by which the hotter particles of water ascend; G is the water-pipe of communication, having the heating pipe of distribution attached between E F, which thence passes backwards and forwards with a very slight slope from the horizontal direction, till it reaches the *poussinière* O P Q. It traverses this apartment, and returns by N N to the orifice of the boiler, H, where it turns vertically downwards, and descends to nearly the bottom of the boiler, discharging at that point the cooled and therefore denser particles of water to replace those which continually issue upwards at D. L R is a tube surmounted with a funnel for keeping the range of pipes always full of water; and K is a syphon orifice for permitting the escape of the disengaged air, which would otherwise be apt to occupy partially the pipes and obstruct the aqueous circulation.

The faster the water gets cooled in the serpentine tubes, the quicker its circulation will be, because the difference of density between the water at the top and bottom of the boiler, which is the sole cause of its movement, will be greater. N represents small saucers filled with water, to supply the requisite moisture to the heated air, and to place



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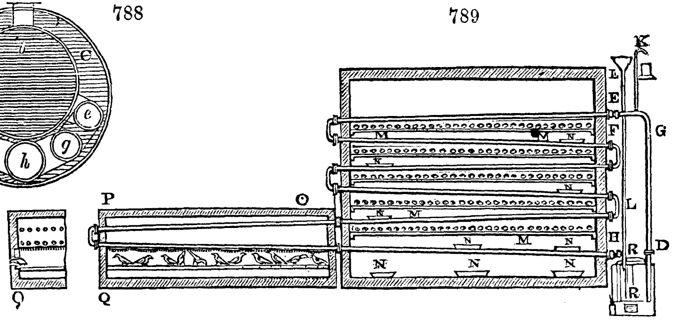

eggs, arranged along the trays M M, in an atmosphere analogous to that under the body of the hen.

When we wish to hatch eggs with this apparatus, the fire is to be kindled in the boiler, and as soon as the temperature has risen to about 100° F., the eggs are introduced; but only one twentieth of the whole number intended, upon the first day; next day, a like number is laid upon the trays, and thus in succession for twenty days, so that upon the twenty-first day the eggs first placed may be hatched, for the most part, and we may obtain daily afterwards an equal number of chicks. In this way, regularity of care is established in the rearing of them.

During the first days of incubation, natural as well as artificial, a small portion of the water contained in the egg evaporates by the heat, through the shell, and is replaced by a like quantity of air, which is afterwards useful for the respiration of the animal. If the warm atmosphere surrounding the eggs were very dry, such a portion of the aqueous part of the eggs would evaporate through the pores of the shells as would endanger the future life of the chick *in ovo*. The transpiration from the body of the hen, as she sits upon her eggs, counteracts this desiccation in general; yet, in very dry weather, many hatching eggs fail from that cause, unless they be placed in moist decomposing straw. The water saucers N N are therefore essential to success in artificial incubation.

After the chickens are hatched they are transferred into the nursery, O Q, on the front side of which there is a small grated trough filled with millet seed. Small divisions are made between the broods of successive days, to enable the superintendent to vary their feeding to their age.

In order to supply an establishment of the common kind, where 100 eggs are to be hatched daily, a dozen of hens would be needed, and 150 eggs must be placed under them, as only two thirds in general succeed. At this rate, 4300 mothers would be required to sit. Now supposing we should collect ten times as many hens, or 43,000, we should not be able to command the above number of chickens, as there is seldom a tenth part of hens in a brooding state. Besides, there would be in this case no fewer than 720 hens every day coming out with a fresh brood of chickens, which would require a regiment of superintendents.

Artificial Incubation by means of Hot Mineral Waters.—This curious process is described very briefly in a letter by M. D'Arcet. The following are extracts from this letter:—

"In June, 1825, I obtained chickens and pigeons at Vichy, by artificial incubation, effected through the means of the thermal waters of that place. In 1827 I went to the baths of Chaudes-Aigues, principally for the purpose of doing the same thing there. Finding the proprietor a zealous man, I succeeded in making a useful application of this source of heat to the production of poultry.

"The advantage of this process may be comprehended, when it is known that the invalids who arrive at Vichy, for instance in the month of May, find chickens only the size of quails; whereas, by this means, they may be readily supplied six months old.

"The good which may be done by establishing artificial incubation in places where not springs exist is *incalculable;* it may be introduced into these establishments without at all interfering with the medical treatment of patients, since the hatching would go on in winter, at a time when the baths for other purposes are out of use.

"There is no other trouble required in breeding chickens, by means of hot baths, than to break the eggs at the proper time; for, when the apartments are closed, the whole of the interior will readily acquire a sufficiently elevated and very constant temperature."

In addition to these details by M. D'Arcet, a letter was received from M. Felgeris, the proprietor of the baths at Chaudes-Aigues (Cantal), in which he describes the success he had in following M. D'Arcet's process. This consists in putting the eggs into a small basket, suspending it in one of the stove-rooms heated by the hot mineral water, and turning round the eggs every day. The very first trial was attended with success, and no failure was experienced in four repetitions of it.

INDIGO. This invaluable blue dye-stuff, for which no tolerable substitute has been found, was known to the ancients as a pigment under the name of *indicum*, whence its present denomination. In modern Europe, it first came into extensive use in Italy, but, about the middle of the 16th century, the Dutch began to import and employ it in considerable quantities. Its general introduction into the dye-houses of both England and France was kept back by absurd laws, founded upon an opinion that it was a fugitive substance, and even prejudicial to the fibre of wool. See Dyeing, p. 419.

The plants which afford this dye-drug grow in the East and West Indies, in the middle regions of America, in Africa, and Europe. They are all species of the genera *Indigofera*, *Isatis*, and *Nerium*.

The following are cultivated:—*Indigofera tinctoria* affords in Bengal, Malabar, Madagascar, the Isle of France, and St. Domingo, an article of middling quality, but in large quantity. The *indigofera disperma*, a plant cultivated in the East Indies and America, grows higher than the preceding, is woody, and furnishes a superior dye stuff. The Guatimala indigo comes from this species. *Indigofera Anil* grows in the same countries, and also in the West Indies. The *Indigofera Argentea*, which grows also in Africa; it yields little indigo, but of an excellent quality. *Indigofera Pseudo-tinctoria*, which is cultivated in the East Indies, furnishes the best of all: the *Indigofera Glauca* is the Egyptian and Arabian species. There are also the *cærulea*, *cinerea erecta*, *hirsuta*, *glabra*, and several others. The *Nerium tinctorium* of the East Indies affords some indigo; as does the *Isatis tinctoria*, or Woad, in Europe; and the *Polygonum tinctorium*.

The districts of Kishenagar, Jessore, and Moorshedabad, in Bengal, ranging from 88° to 90° E. L. and 22½° to 24° N. L., produce the finest indigo. That from the districts about Burdwan and Benares is of a coarser or harsher grain. Tyroot, in lat. 26°, yields a tolerably good article. The portion of Bengal most propitious to the cultivation of indigo lies between the river Hoogly and the main stream of the Ganges.

In the East Indies, after having ploughed the ground in October, November, and the beginning of December, they sow the seed of the indigo plant in the last half of March and the beginning of April, while the soil, being neither too hot nor too dry, is most propitious to its germination. A light mould answers best; and sunshine, with occasional light showers, are most favorable to its growth. Twelve pounds of seeds are sufficient for sowing an acre of land. The plants grow rapidly, and will bear to be cut for the first time at the beginning of July, nay, in some districts, so early as the middle of June. The indications of maturity are the bursting forth of the flower buds, and the expansion of the blossoms; at which period the plant abounds most in the dyeing principle. Another indication is taken from the leaves; which, if they break across, when doubled flat, denote a state of maturity. But this character is somewhat fallacious, and depends upon the poverty or richness of the soil. When much rain falls, the plants grow too rapidly, and do not sufficiently elaborate the blue pigment. Bright sunshine is most advantageous to its production.

The first cropping of the plants is the best; after two months a second is made; after another interval, a third, and even a fourth; but each of these is of diminished value. There are only two croppings in America.

Two methods are pursued to extract the indigo from the plant; the first effects it by fermentation of the fresh leaves and stems; the second, by maceration of the dried leaves; the latter process being most advantageous.

1. *From the recent leaves.*—In the indigo factories of Bengal there are two large stone-built cisterns, the bottom of the first being nearly upon a level with the top of the second, in order to allow the liquid contents to be run out of the one into the other. The uppermost is called the fermenting vat, or the steeper; its area is 20 feet square, and its depth 3 feet; the lowermost, called the beater or beating vat, is as broad as the other, but one third longer. The cuttings of the plant, as they come from the field, are stratified in the steeper, till this be filled within 5 or 6 inches of its brim. In order that the plant, during its fermentation, may not swell and rise out of the vat, beams of wood and twigs of bamboo are braced tight over the surface of the plants, after which water is pumped upon them till it stands within three or four inches of the edge of the vessel. An active fermentation speedily commences, which is completed within 14 or 15 hours; a little longer or shorter, according to the temperature of the air, the prevailing winds, the quality of the water, and the ripeness of the plants. Nine or ten hours after the immersion of the plant, the condition of the vat must be examined; frothy bubbles appear, which rise like little pyramids, are at first of a white color, but soon

become gray-blue, and then deep purple-red. The fermentation is at this time violent, the fluid is in constant commotion, apparently boiling, innumerable bubbles mount to the surface, and a copper-colored dense scum covers the whole. As long as the liquor is agitated, the fermentation must not be disturbed; but when it becomes more tranquil, the liquor is to be drawn off into the lower cistern. It is of the utmost consequence not to push the fermentation too far, because the quality of the whole indigo is deteriorated; but rather to cut it short, in which case there is, indeed, a loss of weight, but the article is better. The liquor possesses now a glistening yellow color, which, when the indigo precipitates, changes to green. The average temperature of the liquor is commonly 85° Fahr.; its specific gravity at the surface is 1·0015; and at the bottom, 1·003.

As soon as the liquor has been run into the lower cistern, ten men are set to work to beat it with oars, or shovels 4 feet long, called *busquets*. Paddle wheels have also been employed for the same purpose. Meanwhile two other laborers clear away the compressing beams and bamboos from the surface of the upper vat, remove the exhausted plant, set it to dry for fuel, clean out the vessel, and stratify fresh plants in it. The fermented plant appears still green, but it has lost three fourths of its bulk in the process, or from 12 to 14 per cent. of its weight, chiefly water and extractive matter.

The liquor in the lower vat must be strongly beaten for an hour and a half, when the indigo begins to agglomerate in flocks, and to precipitate. This is the moment for judging whether there has been any error committed in the fermentation; which must be corrected by the operation of beating. If the fermentation has been defective, much froth rises in the beating, which must be allayed with a little oil, and then a reddish tinge appears. If large round granulations are formed, the beating is continued, in order to see if they will grow smaller. If they become as small as fine sand, and if the water clears up, the indigo is allowed quietly to subside. Should the vat have been over fermented, a thick fat-looking crust covers the liquor, which does not disappear by the introduction of a flask of oil. In such a case the beating must be moderated. Whenever the granulations become round, and begin to subside, and the liquor clears up, the beating must be discontinued. The froth or scum diffuses itself spontaneously into separate minute particles, that move about the surface of the liquor; which are marks of an excessive fermentation. On the other hand, a rightly fermented vat is easy to work; the froth, though abundant, vanishes whenever the granulations make their appearance. The color of the liquor, when drawn out of the steeper into the beater, is bright green; but as soon as the agglomerations of the indigo commence, it assumes the color of Madeira wine; and speedily afterwards, in the course of beating, a small round grain is formed, which, on separating, makes the water transparent, and falls down, when all the turbidity and froth vanish.

The object of the beating is three-fold: first, it tends to disengage a great quantity of carbonic acid present in the fermented liquor; secondly, to give the newly developed indigo its requisite dose of oxygen by the most extensive exposure of its particles to the atmosphere; thirdly, to agglomerate the indigo in distinct flocks or granulations. In order to hasten the precipitation, lime-water is occasionally added to the fermented liquor in the progress of beating, but it is not indispensable, and has been supposed capable of deteriorating the indigo. In the front of the beater a beam is fixed upright, in which three or more holes are pierced a few inches in diameter. These are closed with plugs during the beating, but, two or three hours after it, as the indigo subsides, the upper plug is withdrawn to run off the supernatant liquor, and then the lower plugs in succession. The state of this liquor being examined, affords an indication of the success of both the processes. When the whole liquor is run off, a laborer enters the vat, sweeps all the precipitate into one corner, and empties the thinner part into a spout which leads into a cistern, alongside of a boiler, 20 feet long, 3 feet wide, and 3 deep. When all this liquor is once collected, it is pumped through a bag for retaining the impurities, into the boiler, and heated to ebullition. The froth soon subsides, and shows an oily looking film upon the liquor. The indigo is by this process not only freed from the yellow extractive matter, but is enriched in the intensity of its color, and increased in weight. From the boiler the mixture is run, after two or three hours, into a general receiver called the *dripping vat*, or table, which, for a factory of twelve pairs of preparation vats, is 20 feet long, 10 feet wide, and 3 feet deep; having a false bottom, 2 feet under the top edge. This cistern stands in a basin of masonry (made water tight with Chunam hydraulic cement), the bottom of which slopes to one end, in order to facilitate the drainage. A thick woollen web is stretched along the bottom of the inner vessel, to act as a filter. As long as the liquor passes through turbid, it is pumped back into the receiver. Whenever it runs clear, the receiver is covered with another piece of cloth to exclude the dust, and allowed to drain at its leisure. Next morning the drained magma is put into a strong bag, and squeezed in a press. The indigo is then carefully taken out of the bag, and cut with a brass wire into bits, about 3 inches cube.

which are dried, in an airy house, upon shelves of wicker work. During the drying, a whitish efflorescence comes upon the pieces, which must be carefully removed with a brush. In some places, particularly on the coast of Coromandel, the dried indigo lumps are allowed to effloresce in a cask for some time, and when they become hard they are wiped and packed for exportation.

From some experiments it would appear that the gas disengaged during the middle period of the fermentation is composed in 100 parts of 27·5 carbonic acid, 5·8 oxygen, and 66·7 azote; and towards its end, of 40·5 carbonic acid, 4·5 oxygen, and 55·0 azote. The fermenting leaves apparently convert the oxygen of the atmosphere into carbonic acid gas, and leave its azote; besides the quantity of carbonic acid which they spontaneously evolve. Carbureted hydrogen does not seem to be disengaged. That the liquor in the beating vat absorbs oxygen from the air in proportion as the indigo becomes flocculent and granular, has been ascertained by experiment, as well as that sunshine accelerates the separation of the indigo blue. Out of 1000 parts of the fermented liquor of specific gravity 1·003, the blue precipitate may constitute 0·75 of a part. Such a proportion upon the great scale is however above the average, which is not more than 0·5. When lime water is added, an extractive matter is thrown down, which amounts to from 20 to 47 parts in 1000 of the liquor. It has a dark brown tint, a viscid appearance, an unpleasant smell, and a bitter taste. It becomes moist in damp air, and dissolves in water without decomposition. It is precipitated by lime, alkalis, infusion of galls, and acetate of lead. All indigo contains a little lime derived from the plant, even though none has been used in its preparation.

2. *Indigo from dried leaves.*—The ripe plant being cropped, is to be dried in sunshine from 9 o'clock in the morning till 4 in the afternoon, during two days, and thrashed to separate the stems from the leaves, which are then stored up in magazines till a sufficient quantity be collected for manufacturing operations. The newly dried leaves must be free from spots, and friable between the fingers. When kept dry, the leaves undergo, in the course of 4 weeks, a material change, their beautiful green tint turning into a pale blue-gray, previous to which the leaves afford no indigo by maceration in water, but subsequently a large quantity. Afterwards the product becomes less considerable.

The following process is pursued to extract indigo from the dried leaves. They are infused in the steeping vat with six times their bulk of water, and allowed to macerate for two hours with continual stirring till all the floating leaves sink. The fine green liquor is then drawn off into the beater vat, for if it stood longer in the steeper, some of the indigo would settle among the leaves and be lost. Hot water, as employed by some manufacturers, is not necessary. The process with dry leaves possesses this advantage, that a provision of the plant may be made at the most suitable times, independently of the vicissitudes of the weather, and the indigo may be uniformly made; and moreover, that the fermentation of the fresh leaves, often capricious in its course, is superseded by a much shorter period of simple maceration.

The process for obtaining indigo from the *Nerium* is altogether the same, but hot water has been generally applied to the dried leaves. For woad, hot water must be employed, and also lime water as a precipitant, on account of the small proportion of indigo in the plant. Dilute muriatic acid is digested upon the woad indigo to remove the lime, without which no dye could be precipitated. According to the warmth of the summer and the ripeness of the plant, from 2 to 5 ounces of indigo may be obtained from 100 pounds of the dried woad, or upon an average 4 ounces to the hundred weight.

The indigo found in European commerce is imported from Bengal, Coromandel, Madras, the Mauritius, Manilla, and Java in the Eastern hemisphere; from Senegal, Caraccas, Guatimala, Brazil (South Carolina and Louisiana in small quantity), and formerly from the West India islands, especially St. Domingo. Its quality depends upon the species of the plant, its ripeness, the soil and climate of its growth, and mode of manufacture. The East Indian and Brazilian indigo comes packed in chests, the Guatimala in ox-hides, called *surons.*

The organ which affords the indigo is confined entirely to the pellicle of the leaves, and exists in largest quantity at the commencement of maturation while the plant is in flower. The indigofera is remarkable for giving a blue tinge to the urine of cows that feed upon its leaves.

According to some manufacturers, the plants should be cut down in dry weather, an hour or two before sunset, carried off the field in bundles, and immediately spread upon a dry floor. Next morning the reaping is resumed for an hour and a half, before the sun acts too powerfully upon vegetation; and the plants are treated in the same way. Both cuttings become sufficiently dry by 3 o'clock in the afternoon, so as to permit the leaves to be separated from the stems by thrashing. They are now thoroughly dried in the sunshine, then coarsely bruised, or sometimes ground to powder in a mill, and packed up for the operations of manufacture.

In the spring of 1830 I subjected a variety of specimens of indigo to comparative analyses, by dissolving a few grains of each in strong sulphuric acid, diluting the solutions with an equal volume of water, and determining the resulting shade of color in a hollow prism of plate glass, furnished with a graduated scale. The following are the results, compared to the shade produced by a like weight of absolute indigo.

I. East India Indigos; prices as at the last October sales.

No.	Price.		Real Indigo in 100 parts.	Characters by the Brokers.
	s.	*d.*		
1	3	9	42	Broken, middling violet, and coppery violet spotted.
2	3	6	56·5	Ditto, a little being coppery violet and copper.
3	3	3	46·0	Ditto, middling red violet, dull violet and lean.
4	4	3	54·5	Large broken, and square, even middling red violet.
5	4	2	75·0	Much broken and very small, very crumbly and limy, soft, good violet.
6	4	9	60·0	Square and large broken, ½ middling violet, and ½ good coppery violet.
7	5	3	70·0	Large broken, very good; paste a little limy, good violet.
8	6	6	60·0	Square and large broken, soft, fine paste, fine violet.
9	6	0	66⅔	Square, ditto, good red violet.
10	7	0	75	Square, ditto, fine purple and blue.
11	2	3	37·5	Middling ordinary Madras.
12	3	6	60·0	Good Madras.
13	4	3	58·0	Very fine ditto.
14	2	0	———	Low, pale Oude.
15	2	4	27¾	Middling, ordinary Oude.
16	3	3	54	Good Oude.
17	1	9	29	Lundy, very low quality.

II. American Indigos; wholesale prices at present. (March, 1830.)

Indigo.	No.	Price.		Parts in 100.	Indigo.	No.	Price.		Parts in 100.
		s.	*d.*				*s.*	*d.*	
Caraccas flor. - - -	1	6	0	54½	Guatimala - - -	6	5	0	50
Guatimala - - -	2	5	0	33½	—	7	5	3	35
—	3	3	2	19	—	8	4	8	46
—	4	4	6	32½	—	9	4	8	33½
—	5	5	4	50	—	10	5	4	50

Properties of Indigo.—It possesses a dark blue color, passing into violet-purple, is void of taste and smell, dull, but by rubbing with a smooth hard body, it assumes the lustre and hue of copper. It occurs sometimes less and sometimes more dense *apparently* than water, which circumstance depends upon its freedom from foreign impurities, as well as upon the treatment of its paste in the boiling, pressing, and drying operations. It is insoluble in water, cold alcohol, ether, muriatic acid, dilute sulphuric acid, cold ethereous and fat oils; but boiling alcohol and oils dissolve a little of it, which they deposite on cooling. Creosote has the property of dissolving indigo.

Indigo is a mixture of several dye-stuffs, and other substances. Berzelius found in it a matter resembling vegetable gluten or gliadine, a brown, red, and blue pigment, besides oxyde of iron, clay, lime, magnesia, and silica.

1. Indigo gluten or gliadine is dissolved along with the calcareous and magnesian salts by acids. If the powder be treated with dilute sulphuric acid, if the solution be saturated with carbonate of lime, evaporated to dryness, and its residuum treated with alcohol; the solution thus formed leaves, after being evaporated, a yellow transparent extract, easily soluble in water, more difficultly in acid liquids; showing that acids extract only a portion of the gliadine from the indigo. It yields, by dry distillation, much ammonia, a fetid oil, and comports itself in other respects like vegetable gluten.

2. *Indigo-brown* occurs in combination with lime, as also with vegetable acid in considerable quantity, and more abundantly in the coarser sorts of indigo than in the finer. Indigo purified by acids is to be treated with hot strong caustic ley, which dissolves the indigo-brown; the liquid part of the mixture passes with difficulty through the filter is black-brown, opaque, and holds some indigo-blue in solution, or diffused in fine powder

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The alkali being neutralized with acetic acid, the liquor is to be evaporated, and alcohol poured on the residuum, whereby the alkaline acetate is dissolved out from the brown.

This pigment is a dark brown, almost black, but is not yet entirely deprived of the other constituents of indigo. It is nearly tasteless, is combustible, affords, by dry distillation, ammonia and fetid oil, forms with acids combinations hardly soluble in water, with alkalis soluble ones, but with earths hardly soluble. Lime possesses the property of precipitating the indigo-brown completely from its alkaline solution. Chlorine occasions a pale yellow brownish precipitate, which consists of indigo brown and muriatic acid, but causes no further change. By drying, it becomes again dark colored. Indigo-brown seems to exist also in woad.

3. *Indigo-red*, or more properly red resin of indigo. This may be obtained by boiling alcohol of sp. grav. 0·830 upon some indigo which has been previously treated with acids and alkalis; for the red substance is hardly soluble in cold alcohol. The solution is dark red, opaque, and leaves, by distillation, the indigo-red in the form of a black-brown powder, or a glistening varnish, slightly soluble in alcohol and ether. Alkalis do not dissolve it, but concentrated sulphuric acid forms with it a dark yellow dye, from which water causes no precipitation; wool extracts the color from the acid solution, and becomes of a dirty brown hue. Chlorine does not seem capable of destroying the color, for though it makes it yellow, it becomes as dark as ever on being dried. Indigo-red melts with heat, burns with a bright flame, affords, when heated in vacuo, first a white crystalline sublimate, and then unchanged indigo-red. That white matter is changed by nitric acid into indigo-red.

4. *Indigo-blue*, or pure indigo, remains, after treating the indigo of commerce with dilute acid, alkalis, and alcohol; it retains, however, still traces of the matters thereby extracted, along with some earthy substances. In order to procure indigo-blue in its utmost purity, we must deoxydize the above blue residuum, thus form colorless indigo, which again acquires a blue color from the air, and constitutes the pure pigment. For this purpose the above moist indigo is to be mixed with slaked lime, green sulphate of iron, and hot water in an air-tight matrass. The indigo when deoxydized by protoxyde of iron being soluble in lime-water, the clear yellow solution is to be poured off, and exposed to the air. The indigo absorbs oxygen, and becomes again blue. By digestion with dilute muriatic acid the foreign matters are dissolved, and may then be washed away with distilled water, from the *absolute* indigo.

The indigo-blue obtained in this manner has a cast of purple red, displaying the characteristic copper lustre in a high degree, but in powder, it is blue. It is void of taste and smell, is by my experiments of specific gravity 1·50, affords at 554° Fahr. a purple vapor, and sublimes in shining purple scales, or slender needles in an apparatus open to the air, whereby, however, much of it is destroyed. Some carbon remains after the sublimation. A quick heat produces most sublimate. These needles contain a brown oily matter, which may be dissolved out by means of hot alcohol. Their specific gravity is 1·35, according to Mr. Crum. The sublimate from common indigo does not contain any oil, but some indigo-red and the above white crystalline matter. According to Mr. Crum, indigo-blue consists of carbon, 73·22; oxygen, 12·60; azote, 11·26; hydrogen, 2·92; while according to Dumas, crystallized indigo consists of carbon, 73·26; oxygen, 10·43; azote, 13·81; and hydrogen, 2·50; precipitated indigo consists of carbon, 74·81; oxygen, 7·88; azote, 13·98; and hydrogen, 3·33; sublimed indigo, of carbon, 71·71; oxygen, 12·18; azote, 13·45; hydrogen, 2·66. My own analysis afforded—carbon, 71·37; oxygen, 14·25; azote, 10·00; hydrogen, 4·38. In another analysis of Dumas, 3·93 parts of hydrogen were obtained. Hence we must infer that considerable differences exist in the composition of indigo in its purest state. Reagents act upon it much as upon common indigo. Chlorine, iodine, and bromine convert it into a reddish brown soluble substance. Concentrated sulphuric acid, especially the smoking or anhydrous of Nordhausen, dissolves indigo-blue with the disengagement of heat, but it makes it suffer some modification; for though it retains an intense dark blue color, it has become soluble in water, and may be blanched by light, which does not happen with indigo itself. Nitric acid destroys indigo-blue, forms indigotic (carbazotic) acid, carbonic acid, artificial resin, and bitter principle.

Indigo-blue may be reduced by substances oxydized, with the co-operation of alkalis or alkaline earths; for example, by such substances as have a strong affinity for oxygen, and are imperfectly saturated with this principle, as the sulphurous and phosphorous acids and their salts, the protoxydes of iron and manganese, the protoxyde salts of tin, and the corresponding compounds of chlorine, as the proto-chlorides of tin and iron; and the solution of the former in potash. When in these circumstances, in the presence of alkali, a deoxydation or reduction of the indigo-blue takes place, the other bodies get oxydized by absorption of the oxygen of the indigo-blue; the protoxydes become peroxydes, and the acids in *ous* become acids in *ic*, &c. Several metallic sulphurets also reduce the indigo-blue in the same predicament, as the sulphurets of potassium, of cal cium, of antimony, and of arsenic (orpiment.) A similar influence is exercised by fermenting vegetable substances, such as woad, madder, bran, raw sugar (molasses), starch, sirup, in consequence of the formation of carbonic and acetic acids, by absorption of the oxygen of the indigo-blue, for acetic acid and acetic salts are found in the liquor of the warm blue vat, in which indigo has been reduced by means of woad, madder, and bran.

Formation of colorless reduced indigo-blue, or indigotine.—Purified indigo-blue is to be treated with copperas and slaked lime, as above described; or the clear wine-yellow supernatant liquor of the cold blue-vat mixture is to be taken, run by a syphon into a matrass, a few drops of concentrated acetic or sulphuric acid, deprived of air, are to be poured into it, and the vessel, being made quite full, is to be well corked. The reduced indigo soon falls in white flocks, or crystalline scales. They must be edulcorated upon a filter with water deprived of its air by boiling, then pressed between folds of blotting-paper, and dried under the receiver in vacuo. Indigo-blue may likewise be reduced and dissolved by solution of hydro-sulphuret of ammonia; and the colorless indigotine may be precipitated by muriatic acid.

The reduced indigo is sometimes white at the instant of its elimination, sometimes grayish, of a silky lustre, but becomes very readily greenish, blue green, and blue, in the air; in which case it absorbs, according to Berzelius, 4·2 per cent. of oxygen; but according to Liebeg, 11·5 per cent. It is void of taste and smell, is insoluble in water; well boiled water free from air is not affected by it, but is turned blue by common water. It dissolves in alcohol and ether into a yellow dye; not in dilute acids, but in concentrated sulphuric acid, whereby probably a portion of this is decomposed, and some hyposulphurous acid formed; the color of this solution is blue. Solutions of the caustic and carbonated alkalis, even the alkaline earths, readily dissolve reduced indigo into a wine-yellow liquid; but in contact with air, oxygen is absorbed, and indigo-blue falls, while a purple-colored froth, passing into copper-red, appears upon the surface, just as in the indigo vats of the dyer.

The reduced indigo may be combined, by means of complex affinity, with other bases, with the exception of the oxydes of copper, zinc, and mercury, which oxydize it. These combinations are white, in part crystallizable, become speedily blue in the air, and afford by sublimation indigo-blue. Berzelius formed with lime a two-fold combination; one easily soluble in water, and another difficultly soluble, of a lemon color, which contained an excess of lime; this is formed both in the hot and the cold blue vat; in the latter it is occasioned by an overdose of lime.

When pure indigo-blue is treated with concentrated sulphuric acid, and particularly with six times its weight of the smoking *dry* acid, it dissolves completely, and several different compounds are produced in the solution. There is first a blue sulphate of indigo; secondly, a similar compound with the resulting hyposulphurous acid; thirdly, a combination of sulphuric acid with the purple of indigo (called Phænicin by Crum), a peculiar substance, generated from indigo-blue. These three compounds are here dissolved in an excess of sulphuric acid. The more concentrated the sulphuric acid is, the more blue hyposulphite is formed. The solution in smoking acid, when diluted with water and filtered, affords a considerable precipitate of indigo purple, which that in oil of vitriol does not. The vapor of anhydrous sulphuric acid combines with indigo-blue into a purple fluid.

In order to obtain from the dark blue solution each of these blue acids in a pure state, we must dilute it with forty times its weight of water, and immerse in the filtered liquor, well washed wool or flannel, with which the blue acids combine, while most of the sulphuric acid and some other foreign substances remain free in the liquor. The wool must be then scoured with water containing about a half per cent. of carbonate of ammonia, or potash, which neutralizes both of the blue acids, and produces a blue compound, This being evaporated to dryness at the temperature of 140° F., alcohol of 0·833 is to be poured upon the residuum, which dissolves the blue hyposulphite, but leaves the blue sulphate undissolved. From either salt, by precipitating with acetate of lead, by acting upon the precipitate with sulphureted hydrogen water, and evaporation, either of the two blue acids may be obtained. They may be both evaporated to dryness, especially the blue sulphate of indigo; they both become somewhat moist in the air, they are very soluble in water, and the blue sulphate also in alcohol; they have a not unpleasant smell, and an acid astringent taste.

From these habitudes, particularly in reference to the bases, it appears that indigo-blue does not comport itself like a saline base towards the acids, but rather like an acid, since it enters into the salts, just as the empyreumatic oil of vinegar and oil of turpentine do into resin soaps. The blue pigment of both acids is reduced by zinc or iron without the disengagement of hydrogen gas; as also by sulphureted hydrogen, tepid protochloride of tin, while the liquor becomes yellow.

Indigo-blue sulphate of potash, or ceruleo-sulphate of potash, may be obtained by extracting the blue color from the wool by water containing 1 per cent. of carbonate of potash, evaporating nearly to dryness, treating the extract with alcoho to remove the *indigo-blue hyposulphite*, then with acetic acid and alcohol to remove any excess of carbonate of potash. It is found in commerce under the name of precipitated indigo, indigo paste, blue carmine, and soluble indigo. To prepare it economically, indigo is to be dissolved in ten times its weight of concentrated sulphuric acid; the solution after twenty-four hours is to be diluted with ten times its weight of water, filtered, and imperfectly saturated with carbonate of potash; whereby a blue powder falls down; for the resulting sulphate of potash throws down the ceruleo-sulphate while the hyposulphite of potash remains dissolved. It is a dark blue copper shining powder, soluble in 140 parts of cold water, and in much less of boiling water. It is made use of as a dye, and to give starch a blue tint. When mixed with starch into cakes, it is sold under the name of *blue* for washerwomen.

Ceruleo-sulphate of ammonia may be formed in the same way. It is much more soluble in water. Ceruleo-sulphate of lime is obtained by saturating the above dilute acid with chalk, filtering to separate the undyed gypsum, and washing with water till the purple color be extracted. This liquor, evaporated and decomposed by alcohol, affords a bluish flocky precipitate, which is more soluble in water than common gypsum, and dries up in a purple-blue film. Ceruleo-sulphate of alumina may be obtained by double affinity; it is dark blue while moist, but becomes black-blue by drying, and is soluble in water.

The blue present in all these salts of *ceruline* is destroyed by sunshine, becomes greenish-gray by caustic alkalis; and turns immediately yellow-brown by alkaline earths. But when the solution is very dilute, the color becomes first green, then yellow. The carbonates of alkalis do not produce these changes. Nitric acid decomposes the color quickly. Mr. Crum considers ceruline to be a combination of indigo-blue with water.

Phenicine, or indigo-purple combined with sulphuric acid, is obtained when the solution of indigo-blue in concentrated sulphuric acid has been diluted for a few hours with water, and then filtered. It seems to be an intermediate body into which the indigo-blue passes, before it becomes soluble *ceruline*. Hence it occurs in greater quantity soon after digesting the indigo with the acid, than afterwards. It is dark blue, dissolves gradually in water, affords after evaporation a blue residuum, of the same appearance as the above blue acids. When a salt is added to it a purple precipitate ensues, which is a compound of indigo-purple, sulphuric acid, and the base of the salt. Indigo-purple is reduced by bodies having a strong attraction for oxygen, if a free alkali or alkaline earth be present, and its solution is yellow, but it becomes blue in the atmosphere. According to Mr. Crum, *Phenicine* contains half as much combined water as ceruline.

The table which I published in 1830 (as given above) shows very clearly how much the real quality and value of indigo differ from its reputed value and price, as estimated from external characters by the brokers. Various test or proof processes of this drug have been proposed. That with chlorine water is performed as follows. It is known that chlorine destroys the blue of indigo, but not the indigo-red or indigo-brown, which by the resulting muriatic acid is thrown down from the sulphuric solution in flocks, and the chlorine acts in the same way on the gliadine or gluten of the indigo. Pure indigo-blue is to be dissolved in 10 or 12 parts of concentrated sulphuric acid, and the solution is to be diluted with a given weight of water, as, for example, 1000 parts for 1 of indigo-blue. If we then put that volume of liquor into a graduated glass tube, and add to it chlorine water of a certain strength till its blue color be destroyed by becoming first green and then red-brown, we can infer the quantity of color from the quantity of chlorine water expended to produce the effect. The quantity of real indigo-blue cannot, however, be estimated with any accuracy in this way, because the other coloring matters in the drug act also upon the chlorine; and, indeed, the indigo itself soon changes when dissolved in sulphuric acid even out of access of light, while the chlorine water itself is very susceptible of alteration. Perhaps a better appreciation might be made by avoiding the sulphuric acid altogether, and adding the finely powdered indigo to a definite volume of the chlorine water till its color ceased to be destroyed, just as Prussian-blue is decolored by solution of potash in making the ferro-cyanide.

Another mode, and one susceptible of great precision, is to convert 10 or 100 grains of indigo finely powdered into its deoxydized state, as in the blue vat by the proper quantity of slaked lime and solution of green sulphate; then to precipitate the indigo, collect and weigh it. The indigo should be ground upon a muller along with the quicklime, the levigated mixture should be diluted with water, and added to the solution of the copperas. This exact analytical process requires much nicety in the operator, and can hardly be practised by the broker, merchant, or manufacturer.

Employment of indigo in dyeing.—As indigo is insoluble in water, and as it can penetrate the fibres of wool, cotton, silk, and flax, only when in a state of solution, the dyer must study to bring it into this condition in the most complete and economical manner This is effected either by exposing it to the action of bodies which have an affinity for oxygen superior to its own, such as certain metals and metallic oxydes, or by mixing it with fermenting matters, or, finally, by dissolving it in a strong acid, such as the sulphuric. The second of the above methods is called the warm blue, or pastel vat; and being the most intricate, we shall begin with it.

Before the substance indigo was known in Europe, woad having been used for dyeing blue, gave the name of woad vats to the apparatus. The vats are sometimes made of copper, at other times of iron or wood, the last alone being well adapted for the employment of steam. The dimensions are very variable; but the following may be considered as the average size: depth, 7½ feet; width below, 4 feet, above, 5 feet. The vats are built in such a way that the fire does not affect their bottom, but merely their sides half way up; and they are sunk so much under the floor of the dyehouse, that their upper half only is above it, and is surrounded with a mass of masonry to prevent the dissipation of the heat. About 3 or 3½ feet under the top edge an iron ring is fixed, called the *champagne* by the French, to which a net is attached in order to suspend the stuffs out of contact of the sediment near the bottom.

In mounting the vat the following articles are required: 1. woad prepared by fermentation, or woad merely dried, which is better, because it may be made to ferment in the vat, without the risk of becoming putrid, as the former is apt to do; 2. indigo, previously ground in a proper mill; 3. madder; 4. potash; 5. slaked quicklime; 6. bran. In France, weld is commonly used instead of potash.

The indigo mill is represented in *figs.* 790 and 791. *a* is a four-sided iron cistern cylindrical or rounded in the bottom, which rests upon gudgeons in a wooden frame; it has an iron lid *b*, consisting of two leaves, between which the rod *c* moves to and fro, receiving a vibratory motion from the crank *d*. By this construction, a frame *e*, which is made fast in the cistern by two points *é é*, is caused to vibrate, and to impart its swing movement to six iron rollers *f f f*, three being on each side of the frame, which triturate the indigo mixed with water into a fine paste. Whenever the paste is uniformly ground, it is drawn off by the stopcock g, which had been previously filled up by a screwed plug, to prevent any of the indigo from lodging in the orifice of the cock, and thereby escaping the action of the rollers. The cistern is nearly three feet long.

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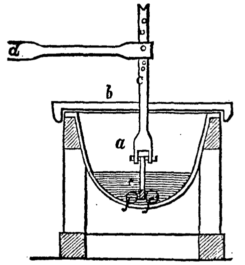

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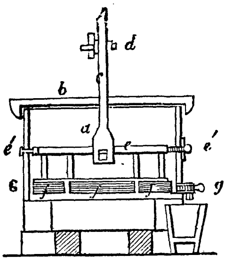

The vat being filled with clear river water, the fire is to be kindled, the ingredients introduced, and if fermented woad be employed, less lime is needed than with the merely dried plant. Meanwhile the water is to be heated to the temperature of 160° Fahr., and maintained at this pitch till the deoxydizement and solution of the indigo begin to show themselves, which, according to the state of the constituents, may happen in 12 hours, or not till after several days. The first characters of incipient solution are blue bubbles, called the flowers, which rise upon the surface, and remain like a head of soap-suds for a considerable time before they fall; then blue coppery shining veins appear with a like colored froth. The hue of the liquor now passes from blue to green, and an ammoniacal odor begins to be exhaled. Whenever the indigo is completely dissolved, an acetic smelling acid may be recognised in the vat, which neutralizes all the alkali, and may occasion even an acid excess, which should be saturated with quicklime. The time for doing this cannot be in general very exactly defined. When quicklime has been added at the beginning in sufficient quantity, the liquor appears of a pale wine-yellow color, but if not, it acquires this tint on the subsequent introduction of the lime. Experience has not hitherto decided in favor of the one practice or the other.

As soon as this yellow color is formed in the liquor, and its surface becomes blue, the vat is ready for the dyer, and the more lime it takes up without being alkaline, the better is its condition. The dyeing power of the vat may be kept up during six months, or more, according to the fermentable property of the woad. From time to time, madder and bran must be added to it, to revive the fermentation of the sediment, along with some indigo and potash, to replace what may have been abstracted in the progress of dyeing. The quantity of indigo must be proportional, of course, to the depth or lightness of the tints required.

During the operation of this blue vat two accidents are apt to occur; the first, which is the more common one, is called the *throwing back*, in French, the *cuve rebuté*, and in German, the *Scharf* or *Schwartzwerden* (the becoming sharp or black); the second is the *putrefaction* of the ingredients. Each is discoverable by its peculiar smell, which it is impossible to describe. The first is occasioned by the employment of too much quicklime, whereby the liquor becomes neutral or even alkaline. This fault may be recognised by the fading of the green, or by the dark green, or nearly black appearance of the liquor; and by a dull blue froth, owing to a film of lime. The remedy for a slight degree of this vicious condition, is to suspend in the liquor a quantity of bran tied up in a bag, and to leave it there till the healthy state be restored. Should the evil be more inveterate, a decoction of woad, madder, and bran must be introduced. Strong acids are rather detrimental. Sulphate of iron has been recommended, because its acid precipitates the lime, while its oxyde reduces the indigo to the soluble state.

The decomposition or putrefaction of the blue vat is an accident the reverse of the preceding, arising from the transition of the acetous into the putrid fermentation, whereby the dyeing faculty is destroyed. Such a misfortune can happen only towards the commencement of working the vat, whilst the woad is still powerful, and very little indigo has been dissolved. Whenever the vat is well charged with indigo, that accident cannot easily supervene. In both of these distemperatures the elevation of the temperature of the vat aggravates the evil.

Dyeing in the blue vat is performed as follows:—

Wool is put into a net, and pressed down into the liquor with rods; but cloth is smoothly stretched and suspended by hooks upon frames, which are steadily dipped into the vat, with slight motions through the liquor; yarn-hanks must be dipped and turned about by hand. All unnecessary stirring of the liquor must however be avoided, lest the oxygen of the atmosphere be brought too extensively into contact with the reduced indigo, for which reason mechanical agitation with rollers in the vat is inadmissible. The stuffs to be dyed take at the first dip only a feeble color, though the vat be strong, but they must be deepened to the desired shade by successive immersions of fifteen minutes or more each time, with intervals of exposure to the air, for absorption of its oxygen.

After the lapse of a certain time, if the fermentative power be impaired, which is recognised by the dye stuffs losing more color in a weak alkaline test ley than they ought, the vat should be used up as far as it will go, and then the liquor should be poured away, for the indigo present is not in a reduced state, but merely mixed mechanically, and therefore incapable of forming a chemical combination with textile fibres. If cotton goods previously treated with an alkaline ley are to be dyed blue, the vat should contain very little lime.

Theory of the Indigo vat.—The large quantity of extractive matter in woad and madder, as also the sugar, starch, and gluten, in the bran and woad, when dissolved in warm water, soon occasion a fermentation, with an absorption of oxygen from the air, but especially from the indigo of the woad, and from that introduced in a finely ground state. When thus disoxygenated, it becomes soluble in alkaline menstrua; the red-brown of the indigo being dissolved at the same time. When lime is added, the indigo-blue dissolves, and still more readily if a little potash is conjoined with it; but whatever indigo-brown may have been dissolved by the potash, is thrown down by the lime. Lime in too large a quantity, however, forms an insoluble combination with the reduced indigo, and thus makes a portion of the dye ineffective; at the same time it combines with the extractive. In consequence of the fermentative action, carbonic acid, acetic acid, and ammonia are disengaged; the first two of which neutralize a portion of the lime, and require small quantities of this earth to be added in succession; hence also a considerable quantity of the carbonate of lime is found as a deposite on the sides and bottom of the vat. In the sound condition of the indigo vat, no free lime should be perceived, but on the contrary a free acid. Yet when the disengaged carbonic and acetic acids saturate the lime completely, no indigo can remain at solution; therefore a sufficient supply of lime must always be left to dissolve the dye, otherwise the indigo would fall down and mix with the extractive matter at the bottom. Goods dyed in the blue vat are occasionally brightened by a boil in a logwood bath, with a mordant of sulpho-muriate of tin, or in a bath of cudbear.

Another mode of mounting the indigo vat without woad and lime, is by means of madder, bran, and potash. The water of the vat is to be heated to the temperature of 122° F.; and for 120 cubic feet of it, 12 pounds of indigo, 8 pounds of madder, and as much bran, are to be added, with 24 pounds of good potashes; at the end of 36 hours, 12 pounds more of potash are introduced, and a third 12 pounds in other 12 hours. In the course of 72 hours, all the characters of the reduction and solution of the indigo become apparent; at which time the fermentation must be checked by the addition of quicklime. The liquor has a bright full color, with a beautiful rich froth. In feeding the vat with indigo, an equal weight of madder and a double weight of potash, should

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be added. The odor of this vat, in its mild but active state, is necessarily different from that of the woad vat, as no ammonia is exhaled in the present case, and the sediment is much smaller. The reduced indigo is held in solution by the carbonated potash, while the small addition of quicklime merely serves to precipitate the indigo-brown.

A potash vat dyes in about half the time of the ordinary warm vat, and penetrates fine cloth much better; while the goods thus dyed lose less color in alkaline and soap solutions. This vat may moreover be kept with ease in good condition for several months; is more readily mounted; and from the minute proportion of lime present, it cannot impair the softness of the woollen fibres. It is merely a little more expensive. It is said that cloth dyed in the potash indigo vat, requires one third less soap in the washing at the fulling mill, and does not soil the hands after being dressed. At Elbeuf and Louviers, in France, such vats are much employed. Wool, silk, cotton, and linen, may all be dyed in them.

Cold vats.—The *copperas* or *common blue vat* of this country is so named because the indigo is reduced by means of the protoxyde of iron. This salt should therefore be as free as possible from the red oxyde, and especially from any sulphate of copper, which would re-oxydize the indigo. The necessary ingredients are: copperas (green sulphate of iron), newly slaked quicklime, finely ground indigo, and water; to which sometimes a little potash or soda is added, with a proportional diminution of the lime. The operation is conducted in the following way: the indigo, well triturated with water or an alkaline ley, must be mixed with hot water in the *preparation* vat, then the requisite quantity of lime is added, after which the solution of copperas must be poured in with stirring. Of this *preparation* vat, such a portion as may be wanted is laded into the dyeing vat. For one pound of indigo three pounds of copperas are taken, and four pounds of lime (or 1 of indigo, 2½ of copperas, and 3 of lime). If the copperas be partially peroxydized, somewhat more of it must be used.

A vat containing a considerable excess of lime is called a *sharp* vat, and is not well adapted for dyeing. A *soft* vat, on the contrary, is that which contains too much copperas. In this case the precipitate is apt to rise, and to prevent uniformity of tint in the dyed goods. The sediment of the copperas vat consists of sulphate of lime, oxyde of iron, lime with indigo brown, and lime with indigo blue, when too much quicklime has been employed. The clear, dark wine yellow fluid contains indigo blue in a reduced state, and indigo red, both combined with lime and with the gluten of indigo dissolved. After using it for some time the vat should be refreshed or fed with copperas and lime, upon which occasion the sediment must first be stirred up, and then allowed time to settle again and become clear. For obtaining a series of blue tints, a series of vats of different strengths is required.

Linen and cotton yarn, before being dyed, should be boiled with a weak alkaline ley, then put upon frames or tied up in hanks, and after removing the froth from the vat, plunged into and moved gently through it. For pale blues, an old, nearly exhausted vat is used; but for deep ones, a fresh, nearly saturated vat. Cloth is stretched upon a proper square dipping frame made of wood, or preferably of iron, furnished with sharp hooks or points of attachment. These frames are suspended by cords over a pulley, and thus immersed and lifted out alternately at proper intervals. In the course of 8 or 10 minutes, the cloth is sufficiently saturated with the solution of indigo, after which it is raised and suspended so as to drain into the vat. The number of dippings determines the depth of the shade; after the last, the goods are allowed to dry, taken off the frame, plunged into a sour bath of very dilute sulphuric or muriatic acid, to remove the adhering lime, and then well rinsed in running water. Instead of the dipping frames, some dyers use a peculiar roller apparatus, called *gallopers*, similar to what has been described under Calico Printing; particularly for pale blues. This cold vat is applicable to cotton, linen, and silk goods.

When white spots are to appear upon a blue ground, resist pastes are to be used, as described under Calico Printing.

The *urine vat* is prepared by digestion of the ground indigo in warmed stale urine, which first disoxygenates the indigo, and then dissolves it by means of its ammonia. Madder and alum are likewise added, the latter being of use to moderate the fermentation. This vat was employed more commonly of old than at present, for the purpose of dyeing woollen and linen goods.

The mode of making the China blue dye has been described under Calico Printing; as well as the *pencil blue*, or blue of application.

A blue dye may likewise be given by a solution of indigo in sulphuric acid. This process was discovered by Barth, at Grossenhayn, in Saxony, about the year 1740, and is hence called the Saxon blue dye. The chemical nature of this process has been already fully explained. If the smoking sulphuric acid be employed, from 4 to 5 parts are sufficient for 1 of indigo; but if oil of vitriol, from 7 to 8 parts. The acid is to be poured into an earthenware pan, which in summer must be placed in a tub of cold water, to pre vent it getting hot, and the indigo, in fine powder, is to be added, with careful stirring, in small successive portions. If it becomes heated, a part of the indigo is decomposed, with the disengagement of sulphurous acid gas, and indigo green is produced. Whenever all the indigo has been dissolved, the vessel must be covered up, allowed to stand for 48 hours, and then diluted with twice its weight of clear river water.

The undiluted mass has a black blue color, is opaque, thick, attracts water from the air, and is called *indigo composition*, or *chemic blue*. It must be prepared beforehand and kept in store. In this solution, besides the *cerulin*, there are also indigo-red, indigo-brown, and gluten, by which admixture the pure blue of the dye is rendered foul, assuming a brown or a green cast. To remove these contaminations, wool is had recourse to. This is plunged into the indigo previously diffused through a considerable body of water, brought to a boiling heat in a copper kettle, and then allowed to macerate as it cools for 24 hours. The wool takes a dark blue dye by absorbing the indigo-blue sulphate and hyposulphite, while at the same time the liquor becomes greenish blue; and if the wool be left longer immersed, it becomes of a dirty yellow. It must therefore be taken out, drained, washed in running water till this runs off colorless, and without an acid taste. It must next be put into a copper full of water, containing one or two per cent. of carbonate of potash, soda, or ammonia (to about one third the weight of the indigo), and subjected to a boiling heat for a quarter of an hour. The blue salts forsake the wool, leaving it of a dirty red-brown, and dye the water blue. The wool is in fact dyed with the indigo-red, which is hardly soluble in alkali. The blue liquor may now be employed as a fine dye, possessed of superior tone and lustre. It is called distilled blue and *soluble blue*. Sulphuric acid throws down from it the small quantity of indigo-red which had been held in solution by the alkali.

When wool is to be dyed with this sulphate of indigo-blue, it must be first boiled in alum, then treated with the blue liquor, and thus several times alternately, in order to produce a uniform blue color. Too long continuance of boiling is injurious to the beauty of the dye. In this operation the woollen fibres get impregnated with the indigo-blue sulphate of alumina.

With sulphate of indigo, not only blues of every shade are dyed, but also green, olive, gray, as also a fast ground to logwood blues; for the latter purpose the preparatory boil is given with alum, tartar, sulphates of copper and iron, and the blue solution; after which the goods are dyed up with a logwood bath containing a little potash.

Table of Stocks, Deliveries, Imports, &c., through the course of 16 Years.

	Stock 31st December.	Delivered 12 Months.	Arrived in 12 months.			Crop of Bengal in course of Shipment.	Prices 31st December.		
			Bengal.*	Madras, Manilla, &c.	Total.		Good and Fine P. V.	Middling and Good Consuming.	Ordinary Consuming.
						maunds.	per lb.	per lb.	per lb.
1836	22,342	22,378	21,829	1,672	23,501	115,500	7 0 @ 8 0	6 0 @ 6 6	5 4 @ 5 10
1837	25,969	18,544	19,409	2,762	22,171	113,600	7 4 “ 8 2	6 3 “ 6 9	5 6 “ 6 6
1838	21,160	28,488	21,670	2,812	23,688	89,000	8 6 “ 9 0	6 9 “ 7 3	5 10 “ 6 6
1839	15,250	23,271	13,882	3,470	17,352	123,000	8 3 “ 9 0	6 0 “ 7 0	5 0 “ 5 9
1840	16,344	25,811	22,823	4,082	26,905	123,000	7 6 “ 8 3	5 3 “ 6 3	4 6 “ 5 0
1841	16,478	26,599	22,687	4,046	26,733	162,000	6 0 “ 6 10	3 4 “ 4 0	2 9 “ 3 3
1842	21,927	27,820	26,594	6,675	33,269	78,900	7 9 “ 8 3	5 0 “ 5 2	4 3 “ 4 9
1843	21,781	22,954	16,920	5,888	22,808	172,000	5 0 “ 5 8	3 6 “ 3 10	2 10 “ 3 4
1844	25,975	32,253	28,228	8,219	36,447	143,500	4 10 “ 5 6	3 8 “ 3 10	3 2 “ 3 6
1845	33,512	29,968	25,458	12,047	37,505	127,800	4 10 “ 5 8	3 3 “ 3 6	2 10 “ 3 3
1846	33,178	28,431	19,438	8,659	28,097	101,300	5 0 “ 6 0	3 8 “ 4 0	3 2 “ 3 6
1847	31,902	30,428	19,576	9,576	29,152	107,200	4 6 “ 5 3	2 10 “ 3 3	2 4 “ 2 8
1848	28,962	27,563	21,119	3,504	24,623	126,700	4 3 “ 5 3	2 10 “ 3 3	2 6 “ 2 9
1849	29,036	32,773	27,464	5,383	32,847	122,000	4 6 “ 5 4	3 6 “ 3 9	3 3 “ 3 5
1850	27,205	28,690	20,057	6,802	26,859	112,000	6 0 “ 7 0	5 2 “ 5 6	4 7 “ 5 0
1851	30,332	29,241	22,572	9,796	32,368	122,000	4 8 “ 5 9	3 7 “ 3 11	3 1 “ 3 6

Stock of E. I. Indigo, in the chief European Ports, at the end of the following Years.

Years.	Rotterdam.*	Amsterdam.*	Antwerp.	Hamburgh.	St. Petersburgh.	Trieste.	Genoa.	Bremen.	France.	London and Liverpool.	Total Stock in Europe.
	chests.	chests.	chests.	chests.	chests.	chests.	chests.	chests.	chests.	chests.	chests.
1843	1,500	1,600	100	255	1,707	150	149	20	6,466	22,381	34,328
1844	664	1,342	170	350	1,600	249	235	10	7,772	26,975	39,367
1845	550	650	100	320	2,011	280	225	60	10,485	34,512	49,193
1846	337	492	100	215	1,389	400	165	50	10,615	33.978	47,741
1847	938	560	60	150	1,918	230	130	20	11,127	32,802	47,935
1848	1042	531	50	450	2,000	200	120	48	7,462	29,412	41,315
1849	595	828	100	550	1,655	150	107	20	4,501	29,240	37,745
1850	395	851	150	340	1,460	150	40	50	5,311	27,215	35,962
1851	80	320	100	260	1,681	50	50	20	5,953	30,452	38,969

Imported for home consumption, in 1850, 7,893,984 pounds; in 1851, 10,073,728 pounds.

Landings, Deliveries, and Stocks of E. I. Indigo.

		Landed.			Delivered.			Stock 1st January, 1852.		
		Bengal.	Madras, &c.	Total.	Home Consumption.	Export.	Total.	Bengal.	Madras, &c.	Total.
In Dec.	1851	177	273	450	679	1,134	1,813	—	—	— chests.
	1850	673	731	1,404	399	418	817	—	—	— "
	1849	—	—	473	433	1,261	1,694	—	—	— "
In 12 months	1851	22,572	9,796	32,368	8,344	20,897	29,241	26,028	4,304	30,332 "
	1850	20,057	6,802	26,859	8,551	20,139	28,690	23,089	4,116	27,205 "
	1849	—	—	32,799	9,209	23,564	33,773	24,989	4,047	29,036 "
	1848	—	—	24,623	10,468	17,095	27,563	23,732	5,230	28,962 "
	1847	—	—	29,252	9,010	21,418	30,428	24,395	7,507	31,902 "
	1846	—	—	28,102	10,546	17,885	28,431	25,333	7,845	33,178 "
	1845	—	—	37,461	10,666	19,302	29,968	26,335	7,177	33,512 "
	1844	—	—	36,808	11,664	20,589	32,253	22,823	3,152	25,975 "
	1843	—	—	22,808	8,253	14,701	22,954	—	—	21,781 "

Indigo from Spanish South America has formed a large feature in our importations of 1851. The landings amount to 7,291 serons, being 4,111 more than the greatest quantity ever before received in one year, and 5,428 more than the average importations of the last ten years.

The deliveries have been still greater; 7,887 serons—equivalent to about 3,900 chests of East Indian production. The parcels, uniformly brought to auction upon arrival, have met with very general attention. The value may be considered relatively as high as Bengal.

That such quantities of this indigo were directed to this country is not the result of increased cultivation, but of the high prices current in 1850, offering a better market than those of the United States or the Mediterranean, the usual destination direct from the producing countries.

Landings, Deliveries, and Stocks of Spanish Indigo.

		Landed.	Delivered.	Stock 1st January.
In December	1851	13 serons	207 serons	— serons
	1850	316 "	127 "	— "
In 12 months	1851	7,291 "	7,887 "	403 "
	1850	3,080 "	2,478 "	999 "
	1849	2,352 "	3,027 "	397 "
	1848	1,153 "	1,967 "	965 "
	1847	2,045 "	1,273 "	1,779 "
	1846	1,265 "	1,414 "	948 "
	1845	1,083 "	1,047 "	1,097 "
	1844	1,132 "	1,095 "	889 "
	1843	2,480 "	2,641 "	891 "
	1842	1,968 "	1,850 "	1,052 "

Prices.—Bengal, fine blue, 5*s.* 10*d.* to 6*s.* per lb.; fine purple and violet, 5*s.* 2*d.* to 5*s.* 9*d.*; fine red violet, 5*s.* 1*d.* to 5*s.* 7*d.*; good purple and violet, 4*s.* 8*d.* to 5*s.*; middling violet, 4*s.* 6*d.* to 4*s.* 8*d.*; middling defective, 4*s.* to 4*s.* 5*d.* Consuming, fine, 4*s.* to 4*s.* 5*d.*; middling and good, 3*s.* 7*d.* to 3*s.* 11*d.*; ordinary, 3*s.* 1*d.* to 3*s.* 6*d.*; ordinary and trash, 2*s.* 3*d.* to 2*s.* 10*d.*

Oude, middling and good, 2*s.* 6*d.* to 3*s.*; ordinary, 2*s.* 2*d.* to 2*s.* 5*d.*

Madras, good and fine, 4*s.* to 4*s.* 6*d.*; middling, 3*s.* to 3*s.* 9*d.*; ordinary, 1*s.* 4*d.* to 2*s.* 9*d.*

Kurpah, fine, 5*s.* to 5*s.* 8*d.*; good, 4*s.* to 4*s.* 9*d.*; middling, 3*s.* 3*d.* to 3*s.* 11*d.*; ordinary 2*s.* 3*d.* to 2*s.* 10*d.*; sweepings, 1*s.* 3*d.* to 1*s.* 6*d.*

Spanish: Guatemala, good and fine, 4*s.* 4*d.* to 5*s.*; middling, 3*s.* 6*d.* to 4*s.* 2*d.*; ordinary, 2*s.* 6*d.* to 3*s.* 3*d.*

Caracca, good, 3*s.* 8*d.* to 4*s.* 6*d.*; ordinary, 2*s.* 6*d.* to 3*s.* 6*d.*

Layton, Hulbert & Co.'s Circular, 7th Jan. 1852.

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* Including Coastwise from Liverpool.

INDIGO, *tested and valued.* Rub one gramme of indigo to a fine powder in a porcelain mortar, pour over it 10 grammes of fuming sulphuric acid, cover it and stir occasionally from 6 to 8 hours. Pour the mixture into an evaporating dish, containing 2 lbs of water, and add 50 grammes of muriatic acid, and heat the whole to boiling, replacing the water lost in vapour.

Dissolve one-fourth of a gramme of chlorate of potash in 100 grammes of water, in a graduated glass tube capable of holding 100 cubic centimetres of water. This quantity of salt suffices even for the very best indigo. This test liquid is to be added to the boiling hot indigo solution in question by degrees, and the quantity of it is noted, which is required to make the colour pass from blue into green, and finally to brownish red. By comparative results with other indigos, and the same test, their relative value is given.

INDIAN RUBBER, is the vulgar name of caoutchouc in this country.

INDUSTRY. See Manufacturing Industry.

INK (*Encre*, Fr.; *Tinte*, Germ.) is a colored liquid for writing on paper, parchment, linen &c. with a pen.

Black ink.—Nutgalls, sulphate of iron, and gum, are the only substances truly useful in the preparation of ordinary ink; the other things often added merely modify the shade, and considerably diminish the cost to the manufacturer upon the great scale. Many of these inks contain little gallic acid, or tannin, and are therefore of inferior quality. To make 12 gallons of ink, we may take—

12 pounds of nutgalls,
5 pounds of green sulphate of iron,
5 pounds of gum senegal,
12 gallons of water.

The bruised nutgalls are to be put into a cylindrical copper, of a depth equal to its diameter, and boiled, during three hours, with three fourths of the above quantity of water, taking care to add fresh water to replace what is lost by evaporation. The decoction is to be emptied into a tub, allowed to settle, and the clear liquor being drawn off, the lees are to be drained. Some recommend the addition of a little bullock's blood or white of egg, to remove a part of the tannin. But this abstraction tends to lessen the product, and will seldom be practised by the manufacturer intent upon a large return for his capital. The gum is to be dissolved in a small quantity of hot water, and the mucilage thus formed, being filtered, is added to the clear decoction. The sulphate of iron must likewise be separately dissolved, and well mixed with the above. The color darkens by degrees, in consequence of the peroxydizement of the iron, on exposing the ink to the action of the air. But ink affords a more durable writing when used in the pale state, because its particles are then finer, and penetrate the paper more intimately. When ink consists chiefly of tannate of peroxyde of iron, however black, it is merely superficial, and is easily erased or effaced. Therefore, whenever the liquid made by the above prescription has acquired a moderately deep tint, it should be drawn off clear into bottles, and well corked up. Some ink-makers allow it to mould a little in the casks before bottling, and suppose that it will thereby be not so liable to become mouldy in the bottles. A few bruised cloves, or other aromatic perfume, added to ink, is said to prevent the formation of mouldiness, which is produced by the ova of infusoria animalcules. I prefer digesting the galls to boiling them.

The operation may be abridged, by peroxydizing the copperas beforehand, by moderate calcination in an open vessel; but, for the reasons above assigned, ink made with such a sulphate of iron, however agreeable to the ignorant, when made to shine with gum and sugar, under the name of japan ink, is neither the most durable nor the most pleasant to write with.

From the comparatively high price of gall-nuts, sumach, logwood, and even oak bark, are too frequently substituted, to a considerable degree, in the manufacture of ink.

The ink made by the prescription given above, is much more rich and powerful than many of the inks commonly sold. To bring it to their standard, a half more water may safely be added, or even 20 gallons of tolerable ink may be made from that weight of materials, as I have ascertained.

Sumach and logwood admit of only about one half of the copperas that galls will take to bring out the maximum amount of black dye.

Chaptal gives a prescription in his *Chimie appliquée aux arts*, which, like many other things in that book, are published with very little knowledge and discrimination. He uses logwood and sulphate of copper, in addition to the galls and sulphate of iron; a pernicious combination, productive of a spurious fugitive black, and a liquor corrosive of pens. It is, in fact, a modification of the vile dye of the hatters.

Lewis, who made exact experiments on inks, assigned the proportion of 3 parts of galls to 1 of sulphate of iron, which, with average galls, will answer very well; but good galls will admit of more copperas.

Gold ink is made by grinding upon a porphyry slab, with a muller, gold leaves along with white honey, till they be reduced to the finest possible division. The paste is then collected upon the edge of a knife or spatula, put into a large glass, and diffused through water. The gold by gravity soon falls to the bottom, while the honey dissolves in the water, which must be decanted off. The sediment is to be repeatedly washed till entirely freed from the honey. The powder, when dried, is very brilliant, and when to be used as an ink, may be mixed up with a little gum water. After the writing becomes dry, it should be burnished with a wolf's tooth.

Silver ink is prepared in the same manner.

Indelible ink.—A very good ink, capable of resisting chlorine, oxalic acid, and ablution with a hair pencil or sponge, may be made by mixing some of the ink made by the preceding prescription, with a little genuine China ink. It writes well. Many other formulæ have been given for indelible inks, but they are all inferior in simplicity and usefulness to the one now prescribed. Solution of nitrate of silver thickened with gum, and written with upon linen or cotton cloth, previously imbued with a solution of soda, and dried, is the ordinary permanent ink of the shops. Before the cloths are washed, the writing should be exposed to the sun-beam, or to bright daylight, which blackens and fixes the oxyde of silver. It is easily discharged by chlorine and ammonia.

A good permanent ink may be made by mixing a strong solution of chloride of platinum with a little potash sugar, and gum to thicken. The writing made therewith should be passed over with a hot smoothing iron, to fix it.

Red ink.—This ink may be made by infusing, for 3 or 4 days in weak vinegar, Brazil wood chipped into small pieces; the infusion may be then boiled upon the wood for an hour, strained, and thickened slightly with gum arabic and sugar. A little alum improves the color. A decoction of cochineal with a little water of ammonia, forms a more beautiful red ink, but it is fugitive. An extemporaneous red ink of the same kind may be made by dissolving carmine in weak water of ammonia, and adding a little mucilage.

Green ink.—According to Klaproth, a fine ink of this color may be prepared by boiling a mixture of two parts of verdigris in eight parts of water, with one of cream of tartar till the total bulk be reduced one half. The solution must be then passed through a cloth, cooled, and bottled for use.

Yellow ink is made by dissolving 3 parts of alum in 100 of water, adding 25 parts of Persian or Avignon berries bruised, boiling the mixture for an hour, straining the liquor, and dissolving in it 4 parts of gum arabic. A solution of gamboge in water forms a convenient yellow ink.

By examining the different dye-stuffs, and considering the processes used in dyeing with them, a variety of colored inks may be made.

China ink.—Proust says, that lamp-black purified by potash ley, when mixed with a solution of glue, and dried, formed an ink which was preferred by artists to that of China. M. Merimée, in his interesting treatise, entitled, *De la peinture à l'huile*, says, that the Chinese do not use glue in the fabrication of their ink, but that they add vegetable juices, which render it more brilliant and more indelible upon paper. When the best lamp-black is levigated with the purest gelatine or solution of glue, it forms, no doubt, an ink of a good color, but wants the shining fracture, and is not so permanent on paper as good China ink; and it stiffens in cold weather into a tremulous jelly. Glue may be deprived of the gelatinizing property by boiling it for a long time, or subjecting it to a high heat in a Papin's digester; but as ammonia is apt to be generated in this way, M. Merimée recommends starch gum made by sulphuric acid (British gum) to be used in preference to glue. He gives, however, the following directions for preparing this ink with glue. Into a solution of glue he pours a concentrated solution of gall-nuts, which occasions an elastic resinous-looking precipitate. He washes this matter with hot water, and dissolves it in a spare solution of clarified glue. He filters anew, and concentrates it to the proper degree for being incorporated with the purified lamp-black. The astringent principle in vegetables does not precipitate gelatine when its acid is saturated, as is done by boiling the nutgalls with limewater or magnesia. The first mode of making the ink is to be preferred. The lamp-black is said to be made in China, by collecting the smoke of the oil of sesame. A little camphor (about 2 per cent.) has been detected in the ink of China, and is supposed to improve it. Infusion of galls renders the ink permanent on paper.

Sympathetic ink. The best is a solution of muriate of cobalt.

Printer's ink. See this article.

By decomposing vanadate of ammonia with infusion of galls, a liquid is obtained of a perfectly black hue, which flows freely from the pen, is rendered blue by acids, is insoluble in dilute alkalis, and resists the action of chlorine. Whenever the metal vana dium shall become more abundant, as it probably may ere long, we shall possess the means of making an ink, at a moderate price, much superior to the tannate and gallate of iron.

To prepare the above vanadic salt cheaply, the cinder or hammerschlag obtained from the iron made at Ekersholm, in Sweden, or other iron which contains vanadium, being reduced to a fine powder, is to be mixed with two thirds of its weight of nitre, and one third of effloresced soda. The mixture is to be ignited in a crucible; cooled and lixiviated, whereby solutions of the vanadates of potash and soda are obtained not pure, indeed, but sufficiently so for being decomposed, by means of sal ammoniac into a vanadate of ammonia. This being rendered nearly neutral with any acid, constitutes an excellent indelible ink.

Ink, indelible, may be prepared by adding lamp-black and Indigo to a solution of the gluten of wheat in acetic acid. This ink is of a beautiful black colour, at the same time cheap, and cannot be removed by water, chlorine, or dilute acids. M. Herberger gives the following directions for its preparation: — Wheat-gluten is carefully freed from the starch, and then dissolved in a little weak acetic acid; the liquid is now mixed with so much rain water that the solution has about the strength of wine vinegar, *i. e.* neutralizes $\frac{1}{16}$ of its weight of carbonate of soda. 10 grs. of the best lamp-black and 2 grs. of indigo are mixed with 4 ozs. of the solution of gluten and a little oil of cloves added. This ink may be employed for marking linen, as it does not resist mechanical force.

Ink, indelible, of Dr. Traill, is essentially the same as the above.

French indelible ink consists of Indian ink diffused through dilute muriatic acid, for writing with quills, and through weak potash lye for writing with steel pens.

Ink, blue. Mr. Stephen's patent blue ink is made by dissolving Prussian blue in a solution of oxalic acid. The blue should be washed in dilute muriatic acid.

M. Hornung has given the following, as the best formula for blue ink: —

Mix 4 parts of perchloride of iron, in solution, with 7·50 parts of water, then add 4 parts of cyanide of potassium dissolved in a little water; collect the precipitate formed, wash it with several additions of water, allow it to drain until it weighs about 200 parts; add to this one part of oxalic acid, and promote the solution of the cyanide by shaking the bottle containing the mixture. The addition of gum and sugar is useless, and even appears to exercise a prejudicial effect on the beauty of the ink. It may be kept without any addition for a long time.

Rev. Mr. Reade's inks.—A series of writing inks of a new composition have been made the subject of a patent by the Rev. J. B. Reade, F. R. S., and they seem to deserve public patronage. They resist equally acids and alkalis, and are well adapted to metallic pens. His inks for marking linen are not acted upon by cyanide of potassium or chloride of lime. His process for obtaining a soluble Prussian blue is new to the chemical world, and inclines to raise a doubt as to the elementary nature of iodine. In the course of his researches, he has discovered two new salts of gold, which he has named ammonia-iodide, and ammonia-periodide, of gold. His specification runs thus: —

1stly. I manufacture in manner following, a blue writing ink, which is wholly free from acid, and therefore well adapted for use with steel pens. I first obtain a solution of iodide of iron by the process ordinarily followed for that purpose, and then dissolve therein half the weight of iodine already employed. I next pour this mixture into a semi-saturated solution of yellow prussiate of potash, employing a weight of this salt nearly equal to the whole weight of iodine used in the above iodine solution. A decomposition of the materials, thus brought together, immediately takes place, when the cyanogen (of the prussiate of potash) and iron combine, and are precipitated in a solid form, and the potassium (of the prussiate) and iodine combine to form a neutral iodide of potassium, which remains in solution with a little excess of iodide of iron. I next filter and wash the solid precipitate of cyanogen and iron (which is soluble Prussian blue), and finally dissolve it in water, which forms the blue ink required. In this process, it will be observed that neither any acid nor persalt of iron is employed, as is usual in the formation of Prussian blue.

I was led to these results by a microscopical examination of the metallic colours in salts of the ashes of plants. I employed iron and iodine to produce the same effects in pure salts; and in the course of my experiments, I ascertained that these two substances (iron and iodine) have so great an affinity for each other, that when placed together without any water, or when rubbed together, they very speedily form a liquid containing an excess of iodine in solution, which, being added to a solution of prussiate of potash, gives the compound of cyanogen and iron, or soluble Prussian blue, which has been just described. The addition of water alters the character of this iodine solution; without water, it turns litmus paper green, and with water it has the usual acid reaction, thus apparently confirming Davy's original doubt as to the elementary character of iodine.

2ndly. I form a neutral iodide of potassium, of great purity, and wholly free from alkaline reaction, in manner following: I take the solution which remained over from the process first described, after the Prussian blue had been precipitated, which solution consisted, as before stated, of a neutral iodide of potassium, with iodide of iron in excess; and I get rid of that excess by the well known processes of fusion and crystallization. The result is an iodide of potassium, which is as pure as when iodine and potassium are made to act directly on one another, and is perfectly free from the alkaline reaction on turmeric paper, which invariably characterizes the most careful preparations of this salt when carbonate of potassa is employed (as usual) in its manufacture. It is also much less deliquescent than the ordinary iodide of potassium of commerce, and. on account of its great purity, much to be preferred in medicinal preparations.

3rdly. I manufacture a blue ink of peculiar intensity, and, therefore, particularly suitable for printing purposes, by using the same materials, and manipulating them in the same way as first described, with the exception that for the iodine wherever it is used, I substitute bromine, and rub up the precipitate in oil.

4thly. I form a bromide of potassium of great purity, and wholly free from alkaline reaction, by treating the bromide of potassium, which remains over in a state of solution from the process last before described, in the same way as the iodide of potassium solution is directed to be used under the second head of this specification.

5thly. I manufacture a very superior black writing ink, by adding to gall ink of a good quality soluble Prussian blue, described under the first head of this specification. The addition of this Prussian blue makes the ink, which was already proof against alkalines, equally proof against acids, and forms a writing fluid, which cannot be erased from paper by any common method of fraudulent obliteration, without the destruction of the paper.

6thly. I manufacture in manner following a red writing ink which is generally superior to the common solutions from peach wood and Brazil wood, not only in permanent brilliancy of colour, but also in its freedom from acid, and consequent fitness for use with steel pens. I first boil cochineal repeatedly in successive quantities of pure water, till it ceases, or nearly so, to give out any colouring matter. I then boil it in water containing liquor ammoniæ, which combines after the manner of an alkali with an acid, with the residue of colouring matter, and leaves the insect matter nearly white. The liquid products of these successive boilings are then thrown together into an earthenware vessel, and, in order to get rid of a peculiar element or principle, still combined with the colouring matter, and which has a great affinity for iron, I precipitate the colouring matter with ammonia-bichloride of tin. The precipitate is afterwards dissolved in ammonia, and protiodide of tin added, till a sufficient degree of brilliancy of colour is obtained, which completes the process, water being added *ad libitum*, according to the degree of body required to be given to the ink.

7thly. I manufacture by the improved process following a marking ink which may be used with steel pens, and is not only of great intensity of colour, but comes out most readily on the application of heat. I rub together in a mortar nitrate of silver and the proper equivalent of tartaric acid in a dry state. I then add water, on which crystals of tartrate of silver are formed and the nitric acid set free. I next neutralize this acid by adding liquor ammoniæ, which also dissolves the tartrate of silver. I finally add gum, colouring matter, and water, in the usual way, and in quantities which may be varied at pleasure. By this process the nitric acid, which is essential to a good marking ink, is retained and the tartrate of silver formed is soluble in less than half the quantity of liquor ammoniæ ordinarily required when tartrate of silver is the basis of the ink. The tedious operation of filtering and washing the carbonate of silver in order to form the tartrate is also thereby entirely dispensed with.

8thly. I manufacture in manner following a marking ink, differing from the preceding and all other marking inks containing salts of silver only, in this respect, that it cannot be acted upon by the common solvents of salts of silver, as cyanide of potassium, or chloride of lime, and is so far, therefore, more indelible. I take the ink, as it has been formed by the process last described, and add to it an ammoniacal solution of an oxide or salt of gold. I have used for this purpose the purple of Cassius, the hyposulphite of gold, the ammonia-iodide of gold, and ammonia-periodide of gold. The two last salts, which I believe to be new salts, I obtain by dissolving iodine in liquor ammoniæ, under the application of heat; an operation, however, which requires to be conducted with great caution in order to prevent the formation of the explosive compound, the teriodide of nitrogen. This iodine solution is a very speedy solvent of gold. If gold leaf be placed upon it without the addition of water, a black oxide of gold is formed, which immediately dissolves, but if it be diluted with water, the process of oxidation is less rapid, and the gold leaf assumes a fine purple colour (not black), before solution. This salt of gold crystallizes in four-sided prisms, which are soluble in water. A few drops of this solution placed on a slip of glass generally form microscopic arborescent crystals, from which, under the application of heat, both the iodine and ammonia may be volatilized, and arborescent metallic gold alone remains. If a moderate heat only is employed, one equivalent only of iodine is expelled, and white crystals of ammonia-iodide of gold remain.

9thly. I manufacture a blue printing ink by taking the soluble precipitate of cyanogen and iron, obtained by the process described under the first head of this specification, and rubbing up the same in oil, after the manner ordinarily followed in the manufacture of printing inks; or by boiling down the blue writing ink, produced by the said process to a sufficient consistence, and then rubbing up the same in oil.

10thly. I manufacture a black printing ink by boiling down the black writing ink, produced from the materials, and by the process described under the fifth head of this specification, and rubbing it up in oil as aforesaid.

11th. I manufacture a red printing ink by taking the ammoniacal solution of cochineal, obtained by the process described under the sixth head of this specification, and rubbing it up in oil, adding protiodide of tin according to the degree of lustre required; or by boiling down the red writing ink, produced by the said process, to a sufficient consistence, and then rubbing up the same in oil as aforesaid.

And 12th, I manufacture a black printing ink by boiling chips of logwood (for which an extract of logwood may be substituted), or other dye woods, containing colouring matter and tannin, along with as much of proto-salt or persalt of iron or copper, or other precipitate of tannin, as will be equal to about twice the weight of the tannin contained in the wood or extract employed; whereby I obtain a black or blueish black precipitate; the blueness of which I diminish, as may be required, by the addition of bichromate of potash, more or less. I finally rub up the whole in oil as aforesaid, adding a small quantity of the lamp-black, or other black colouring matter, ordinarily employed in the manufacture of black printing inks.

INULINE (Eng. and Fr.) is a substance first extracted from the root of the ***Inula-Helenium***, or Elecampane. It is white and pulverulent like starch; and differs from this substance chiefly because its solution, when it cools, lets fall the inuline unchanged in powder, whereas starch remains dissolved in the cold, as a jelly or paste.

Inuline is obtained by boiling the root sliced in 3 or 4 times its weight of water, and setting the strained decoction aside till it cools, when the pulverulent inuline precipitates. It exists also in the roots of colchicum, and pellitory.

IODINE (*Iode*, Fr.; *Iod*, Germ.) is one of the archæal undecompounded chemical bodies, which was discovered accidentally in 1812 by M. Courtois, a manufacturer of saltpetre, in the mother-waters of that salt. Its affinities for other substances are so powerful as to prevent it from existing in an insulated state. It occurs combined with potassium and sodium in many mineral waters, such as the brine spring of Ashby-de-la-Zouche, and other strongly saline springs. This combination exists sparingly in sea-water, abundantly in many species of *fucus* or sea-weed, and in the kelp made from them; in sponges; in several marine *molluscæ*, such as the *doris*, the *venus*, oysters, &c.; in several polyparies and sea plants, as the *gorgonia*, the *zostera marina*, &c.; particularly in the mother-waters of the salt-works upon the Mediterranean sea; and it has been found in combination with silver, in some ores brought from the neighborhood of Mexico.

Iodine is most economically procured from the mother-water of kelp, as furnished by those manufacturers of soap in Scotland and elsewhere who employ this crude alkaline matter. By pouring an excess of sulphuric acid upon that liquid, and exposing the mixture to heat in a retort, iodine rises in *violet* vapors (whence its name), and condenses in the receiver into black, brilliant, soft, scaly crystals, resembling graphite or plumbago. An addition of the peroxyde of manganese to the above mixture, favors the production of iodine. Souberain has proposed as a means of extracting it in greater abundance from a given quantity of the said mother-waters, to transform the iodide of potash or soda, present, into an insoluble iodide of copper, by pouring into them solution of sulphate of copper, which precipitates first of all one half of the iodine. He then decants the supernatant liquor, and adds to it a fresh quantity of the sulphate along with some iron filings. The latter metal seizes the oxygen and sulphuric acid of the cupreous salt, sets the copper free, which then seizes the other half of the iodine. To separate this iodide from the remaining iron filings, he agitates the whole with water, and decants the liquor. The filings immediately subside, but the iodide of copper remains for some time in a state of suspension. This compound, separated by a filter cloth, is to be mixed with twice its weight of the black peroxyde of manganese, and as much sulphuric acid as will make the mixture into a paste; which mixture being introduced into a retort, and distilled, the iodine comes over in its characteristic violet vapors, which are condensed into the glistening black substance in the receiver.

Iodine is always solid at atmospheric temperatures, though it slowly flies off with a peculiar offensive penetrating odor somewhat like chlorine. Its specific gravity is 4·946 at the temperature of 58° Fahr. Its prime equivalent, according to Berzelius, is 63·283, one volume of hydrogen being 1·000; but 126·566, if two volumes of hydrogen be reckoned unity, as most British chemists estimate it, from the composition of water. It possesses in a high degree electro-negative properties, like oxygen and chlorine; and therefore makes its appearance at the positive pole, when its compounds are placed in the voltaic circuit. It stains the skin yellow; and if applied for some time to it, is apt to produce painful ulcerations.

Iodine melts only at about 390° Fahr.; but with the vapor of water it volatilizes at 212° It has a great affinity for hydrogen, and constitutes by that union hydriodic acid; a compound resembling in some respects muriatic or hydrochloric acid. It also can be combined with oxygen, and forms thereby iodic acid. Its compounds with carbon, phosphorus, sulphur, chlorine, azote, and many metals, have not been applied to any manufacturing purpose, and therefore need not be described here.

The chief application of iodine in the arts, is for the detection of starch, which its watery solution, though containing only one part in 5000, does readily, by the production of a deep purple color; this vanishes by exposing the starch to the air for some time, or more quickly by heating it.

As a medicine, iodine and its compounds, such as the iodides of potassium and iron, are supposed to possess great powers in resolving glandular swellings. The periodide of mercury is a brilliant red pigment, but somewhat evanescent.

Chlorine, bromine, and iodine, are frequently associated; and it has hitherto been reckoned a difficult problem to separate them from one another. The following plan is proposed by Mr. Lövig.

Heat the mixture of the dried chloride and bromide (or chloride and iodide) while a current of chlorine is made to pass over it, till no more bromine is carried off by the chlorine. Receive the gases in a solution of potash; saturate this fluid mixture of the chloride of potassium, and the chlorate and bromate of potash with nitric acid, adding afterwards nitrate of silver. A mixture of bromate and chloride of silver will precipitate. Dry the precipitate, calcine it, and calculate the proportion of bromine from the volume of oxygen gas now disengaged. It would be preferable to digest in a vial, the precipitate while moist, along with water of baryta, which decomposes the bromate of silver without acting upon the chloride. The excess of baryta being thrown down by carbonic acid, and the liquid being evaporated, a bromate of baryta is obtained, which may be washed with alcohol of 0·840. The solution of bromate of baryta may also be neutralized by nitric acid, and the bromic acid may be precipitated by nitrate of silver. The same method is applicable to the separation of iodine from chlorine.

After throwing down the solution of the mixed salts by nitrate of silver, Berzelius digests the washed precipitate in a closed bottle of water of baryta; whence results bromate of baryta without any chloride of barium. On evaporating the liquor we obtain crystallized bromate of baryta, which may be freed from a small accidental quantity of chloride, by washing with alcohol at 0·840. By calcination we then obtain bromide of barium, which, being distilled with sulphuric acid and peroxyde of manganese, affords bromine.

IRIDIUM is a metal discovered by Descotils in 1803, as also by Tenant in 1804; and is so called because its different solutions exhibit all the colors of the rainbow. It occurs only in the ore of platinum, being found there in two states; 1. united to that metal, and 2. as alloy of osmium and iridium, in the form of small, insulated, hard grains. Iridium is the most refractory of all the metals; and appears as a gray metallic powder. It is not fused by the flame of the hydroxygen lamp.

IRON (*Fer*, Fr.; *Eisen*, Germ.) is a metal of a bluish-gray color, and a dull fibrous fracture, but it is capable of acquiring a brilliant surface by polishing. Its specific gravity is 7·78. It is the most tenacious of metals, and the hardest of all those which are malleable and ductile. It is singularly susceptible of the magnetic virtue, but in its pure state soon loses it. When rubbed it has a slight smell, and it imparts to the tongue a peculiar astringent taste, called chalybeate. In a moist atmosphere, iron speedily oxydizes, and becomes covered with a brown coating, called rust.

Every person knows the manifold uses of this truly precious metal; it is capable of being cast in moulds of any form; of being drawn out into wires of any desired strength or fineness; of being extended into plates or sheets; of being bent in every direction; of being sharpened, hardened, and softened at pleasure. Iron accommodates itself to all our wants, our desires, and even our caprices; it is equally serviceable to the arts, the sciences, to agriculture, and war; the same ore furnishes the sword, the ploughshare, the scythe, the pruning hook, the needle, the graver, the spring of a watch or of a carriage, the chisel, the chain, the anchor, the compass, the cannon, and the bomb. It is a medicine of much virtue, and the only metal friendly to the human frame.

The ores of iron are scattered over the crust of the globe with a beneficent profusion, proportioned to the utility of the metal; they are found under every latitude, and every

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zone; in every mineral formation, and are disseminated in every soil. Considered in a purely mineralogical point of view, without reference to their importance for reduction, they may be reckoned to be 19 in number; namely, 1. native iron of three kinds: pure, nickeliferous, and steely; 2. arsenical iron; 3. yellow sulphuret of iron; 4. white sulphuret of iron; 5. magnetic sulphuret of iron; 6. black oxyde of iron, either the loadstone, or susceptible of magnetism, and titaniferous; 7. compact *fer oligiste*, specular iron ore, as of Elba, and scaly *fer oligiste;* 8. hematite, affording a red powder; 9. hematite or hydrate of iron, affording a yellow powder, of which there are several varieties; 10. pitchy iron ore; 11. siliceo-calcareous iron, or yenite; 12. sparry carbonate of iron, and the compact clay iron-stone of the coal formation; 13. phosphate of iron; 14. sulphate of iron, native copperas; 15. chromate of iron; 16. arseniate of iron; 17. muriate of iron; 18. oxalate of iron; 19. titanate of iron.

Among all these different species, ten are worked by the miner, either for the sake of the iron which they contain; for use in their native state; or for extracting some principles from them advantageous to the arts and manufactures; such are arsenical iron, sulphate of iron, sulphuret of iron, and chromate of iron.

1. *Native iron* A. Pure.—This species is very rare, and its existence was long matter of dispute; though it has been undoubtedly found not only in volcanic formations, but in veins properly so called. It is not entirely like our malleable iron; but is whiter, more ductile, more permanent or less oxydizable in the air, and somewhat less dense. Among the best attested examples of pure native iron is that observed by M. Schreber, in the mountain of Oulle near Grenoble. The metal was entangled in a vein running through gneiss, and appeared in ramifying stalactites, enveloped in fibrous brown-oxyde of iron mixed with quartz and clay.

B. *The native nickeliferous* or *meteoric iron* is very malleable, often cellular, but sometimes compact, and in parallel plates, which pass into rhomboids or octahedrons. It is naturally magnetic, and by its nickel is distinguishable from terrestrial native iron. Macquart, in describing the famous mass found at mount Kemir in Siberia, says that the iron is perfectly flexible, and fit for making small instruments at a moderate heat; but in too strong a fire, the metal becomes short, brittle, and falls into grains under the hammer. Meteoric iron is covered with a sort of varnish which preserves its surface from the rusting action of the air; but this preservative property does not extend to the interior. Chladni has given a list of masses of meteoric iron, which have been known to fall at different times from the atmosphere, and of many specimens which indicate their atmospheric origin, by their aspect and composition. A portion of the mass of meteoric iron found at Santa-Rosa near Santa-Fe-de-Bogota, was made into a sword and presented to Bolivar.

C. *Native steel-iron.*—This substance has all the characters of cast-steel; it occurs in a kind of small button ingots, with a finely striated surface, and a fracture exceedingly fine grained. It is hardly to be touched by the file, and will scarcely flatten under the hammer. M. Mossier found this native steel at the village of Bouiche, near Nery, department of the Allier, in a spot where there had existed a seam of burning coal. A mass of 16 pounds and 6 ounces of native steel was discovered in that place, besides a great many small globules.

2. *Arsenical iron, Arsenikkies,* or *Mispickel,* is a tin-white mineral, which emits a garlic smell at the blowpipe, or even when sparks are struck from it by steel, accompanied with a small train of white smoke. It contains generally more or less sulphur, and sometimes a little silver, associated with metallic arsenic and iron.

3. *Yellow sulphuret of iron,* commonly called *Marcasite,* or Martial pyrites. The bronze or brass yellow color enables us to recognise this mineral. At the blowpipe it gives off its sulphur, and is converted into a globule attractable by the blowpipe. It is a bisulphuret of iron containing 32 of sulphur and 28 of metal.

Copper pyrites may be distinguished from it by its golden yellow color, which is frequently iridescent, and by its inferior hardness; for it does not strike fire with steel, like the preceding persulphuret. There is no vein, stratum, or mass of metallic ore which does not contain some iron pyrites; and it is often the sole mineral that fills the veins in quartz. It sometimes contains gold, and at other times silver.

4. *White sulphuret of iron.*—This is distinguishable from the preceding species only by its color and form of crystallization, and was hence till lately confounded with it by mineralogists. Its surface is often radiated.

5. *Magnetic sulphuret of iron,* the *Magnetkies* of the Germans.—This ore is attractable by the magnet like common iron. Its color is reddish-yellow, passing into brown: its fracture is rough. It consists of 16 of sulphur and 28 of iron.

6. *Black oxyde of iron, magnet ore,* or *native loadstone.*—One variety of this species has two poles in each specimen, which manifest a repulsive action against the corresponding poles of a magnetic needle. All the varieties furnish a black powder. Its external color is a gray approaching to that of metallic iron, but somewhat duller;

with occasional iridescence of surface. Neither nitric acid nor the blowpipe has any action upon it. Its specific gravity varies from 4·24 to 5·4; and its constituents are 71·86 peroxyde, and 28·14 protoxyde, according to Berzelius; or in 100 parts, 71·74 of metallic iron, and 28·26 of oxygen. Assuming the prime equivalent of iron to be 28 with the British chemists, then an ore consisting, like the above, of two prime proportions of peroxyde, and one of protoxyde, would be represented by the number 116 = 80 + 36; and would consist in 100 parts, of iron 72·4, oxygen 27·6.

Magnetic iron-ore belongs to primitive rock formations, and occurs abundantly in Sweden, Dalecarlia, Norway, Siberia, China, Siam, and the Philippine isles; but it is rare in England and France. It is worked extensively in Sweden, and furnishes an excellent iron.

The titaniferous oxyde of iron, or iron sand, is also attractable by the magnet. Its color is a deep black, with some metallic lustre; it is perfectly opaque; its fracture is conchoidal; it is hard and difficult to grind under the pestle into a dull black powder, which stains the fingers when it is very fine; it melts at a high heat into a black enamel without lustre. All volcanic rocks contain a greater or less quantity of titanic iron-ore, disseminated through them, which may be recognised by its brilliant metallic lustre, and its perfect conchoidal fracture.

7. *Fer oligiste, iron-glance, specular iron, and red iron ore.*—This ore has the color of polished steel; and the light transmitted through the thin edges of its crystals appears of a beautiful red. Its powder is always of a well marked brown-red hue, passing into cherry-red, which distinguishes it from the black-oxyde ore. Its fracture is rough, or vitreous in certain varieties; it breaks easily; but it is hard enough to scratch glass. It usually contains from 60 to 70 of metallic iron in 100 parts; the equivalent proportion of oxygen in the pure red oxyde of iron being 30 parts combined with 70 of metal. It is a mistake to suppose any specular iron ore capable of yielding 85 per cent. of iron, for 100 parts of even protoxyde of iron contain only 77·77 parts of metal.

The compact variety comprises the crystals of the island of Elba, and of Framont in the Vosges, which have a rough-grained fracture. It exists in very great masses, constituting even entire mountains; in the cavities and fissures of these masses, the beautiful crystals so much prized by collectors of minerals, occur.

The island of Elba is equally celebrated for its inexhaustible abundance of rich specular iron ore, and for the immemorial antiquity of its mining operations. *Fig.* 792 is a vertical section passing through the three workings, called Pietamonte (D), Sanguinaccio (E), Antenna (F), through an ancient excavation *a*, through the coast *o*, and the mole *p*, ending at the canal of Piombino. The total height of the metalliferous mountain above the level of the sea, is no more than 180 metres, or 600 feet.

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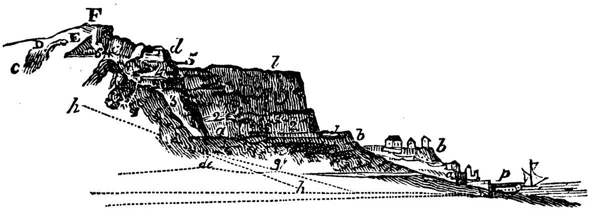

The rock which constitutes the body of this little mountain *d l*, is called *bianchetta* by the workmen. It is a white slaty talc, slightly ochreous, or yellowish, consisting chiefly of silica and alumina, with some magnesia.

The ore of Antenna (F) is a very hard compact *fer oligiste*, of a brilliant metallic aspect. The workable bed has a height of 66 feet, and consists of metalliferous blocks mixed confusedly with sterile masses of the rock; the whole covered with a rocky detritus, under a brownish mould. From its metallic appearance and toughness, this bed is called *vena ferrata*, the iron vein. In Pietamonte the workable bed is composed entirely of micaceous specular iron ore (*fer oligiste*), with its fissures filled with yellow ochre. This bed rests upon the rock called *bianchetta;* the brilliant aspect of ore in this place has gained for it the name of *vena lucciola.*

The metalliferous hill *d l*, extends to the north-east, about a mile beyond the workings D E F. The ore contains about 65 per cent. of iron, and is smelted in Catalan forges.

The following description of the figure will make the structure of this extraordinary mine well understood. *a*, is a great excavation, the result of ancient workings.

1, 1; 2, 2; 3, 3, 4, 4, 5, 6, and 7, are roads for carrying off the rubbish, in correspondence with the several working levels.

b, *b*, *b*, masses of old rubbish (*deblais*).

c, *c*, ditto, from the present workings D, E, F.

d, the rocky mass called bianchetta, against which the ore extracted from *a* abuts.

e, the surface of a bed of ore, near the streamlet *g*.

f, *f*, indication of beds of iron pyrites and *fer oligiste*.

g, a small rivulet proceeding from the infiltration of rains, and which is impregnated with acidulous sulphate of iron.

h, *h*, ravine which separates the metalliferous hill *d l* from the barren hill *i*.

k, masses of slags from ancient smelting operations; such are very common in this island. None of any consequence now exist; nearly the whole of the ore being exported to Tuscany, the Romagna, the Genoese territories, Piedmont, Naples, and Corsica.

l, a considerable body of rubbish from ancient workings, towards the summit of the metalliferous hill *d*, *l*.

m, *m*, part of this hill covered with rubbish, the result of old workings.

n, the site called *Vigneria*.

o, houses upon the shore called *Marina de Rio*, where the workpeople live, and the mineral is kept in store.

p, wooden pier (*mole*) whence the ore is shipped; terminated by a small tower, *q*.

Compact *fer oligiste* occurs also in the Vosges, in Corsica, at Altenberg and Freyburg, in Saxony, Presnitz, in Bohemia, Norberg and Bisberg, in Sweden, &c.

The varieties called specular *fer oligiste*, and scaly *fer oligiste*, or iron-glance, do not differ essentially from the compact. None of them affects the magnetic needle, and their powder is a red of greater or less vivacity.

8. *Red oxyde of iron.*—The varieties included under this species afford a red powder, do not affect the magnetic needle, and are destitute of metallic lustre. At the blowpipe they all become black, or deep brown; and then they act on the needle. The crystallized variety consists of 70 iron and 30 oxygen in 100 parts. The concretionary kind, or *hematite*, has a brown-red color; is solid, compact, and sometimes very hard; its surface may be filed and polished so as to acquire a lustre almost metallic; its internal structure is fibrous, and it exhibits sometimes a resemblance to splinters of wood. Its outer surface is constantly concretionary, mammelated, and presents occasionally sections of a sphere, or cylinders attached to each other. This is the blood-stone of the burnisher of metals. It is a very common mineral. The ochry variety or red-iron-ochre is distinguished from the solid hematite by the brightness of its color. It is used as a pigment.

9. *Brown oxyde of iron, brown iron-stone.*—This affords always a yellow powder, without any shade of red, which passes sometimes into the bistre brown, or velvet black. At the blowpipe this oxyde becomes brown, and very attractable by the magnet; but after calcination and cooling, the ore yields a red powder, which stains paper nearly as red as hematite does, and which is much employed in polishing metals. All the yellow or brown oxydes contain a large proportion of water, in chemical combination; and hence this species has been called hydrate of iron. There are several varieties which assume globular, reniform, stalactitic, and fruticose shapes. As impure varieties of the species we must consider some of the clay-iron ores, such as the granular, the common, the pisiform, and the reniform clay-iron ore. According to D'Aubuisson, the present species consists of peroxyde of iron, from 82 to 84 *per cent.*; water, 14 to 11; oxyde of manganese, 2; silica, 1 to 2. It is therefore a hydrated peroxyde of iron; and ought by theory to consist, in its absolute state, of 81·63 peroxyde, and 18·37 water. It occurs both in beds and veins. The *œtites* or eagle-stones form a particular variety of this ore. On breaking the balls, so named, they are observed to be composed of concentric coats, the outside ones being very hard, but the interior becoming progressively softer towards the centre, which is usually earthy and of a bright yellow color; sometimes, however, the centre is quite empty, or contains only a few drops of water. Œtites occur in abundance, often even in continuous beds in secondary mountains, and in certain argillaceous strata. These stones are still considered by the French shepherds as amulets or talismans, and may be found in the small bags which they suspend to the necks of their favorite rams; and they are in such general use, that a large quantity is annually imported into France from the frontiers of Germany, for this superstitious purpose. When smelted, they yield a good iron.

The variety called *granular brown oxyde*, or *bone ore*, is merely a modification of the preceding. It occurs in grains nearly round, varying in size from a millet seed to a pea, each being composed of concentric coats, hard outside and soft within. They are generally agglutinated by a calcareous or argillaceous paste; but are occasionally quite loose. This ore occurs in calcareous formations, and is sometimes accompanied with shells, such as *terebratulæ*. The brittle quality of the iron afforded by it has been ascribed to the phosphorus derived from the large quantity of organic bodies, with which the ore is frequently mixed. The bog-iron ore and swamp-iron ore belong to this species.

10. *Pitchy hydrate of iron.*—This is a rare mineral of a resinous aspect, found in a vein in the mine of Braunsdorf, two leagues from Freyberg, and seems to consist of red oxyde of iron and water.

11. *Yenite* is a mineral species, rather rare, composed of red oxyde of iron, silica, and lime.

12. *Carbonate of iron, sparry iron, or brown-spar.*—This important species has been divided into two varieties; spathose iron and the compact carbonate. The first has a sparry and lamellar fracture; with a color varying from yellowish-gray to isabella yellow, or even to brownish-red. It turns brown without melting at the blowpipe, and becomes attractable by the magnet after being slightly roasted in the flame of a candle. Even by a short exposure to the air, after its extraction from the mine, it also assumes the same brown tint, but without acquiring the magnetic quality. It affords but a slight effervescence with nitric acid, changing merely to a red-brown color. Its specific gravity varies from 3·00 to 3·67. Its primitive form is like that of carbonate of lime, an obtuse rhomboid. Without changing this form, its crystals are susceptible of containing variable quantities of carbonate of lime, till it passes wholly into this mineral. Manganese and magnesia enter also occasionally into its composition.

Sparry carbonate of iron belongs to primitive formations; forming powerful veins in mountains of gneiss, and is associated in these veins with quartz, copper pyrites, gray copper, fibrous brown oxyde of iron, and a variety of ramose carbonate of lime, vulgarly called *flos ferri.* Thus it is found at Allevard and Vizille, near Grenoble, at Saint-George d'Huretière, in the Alps of Savoy; at Baigorry, in the Lower Pyrenees; at Eisenerz, in Styria; at Huttenberg, in Carinthia; at Schwartz, in the Tyrol; in Saxony, Hungary, other places in Germany, as also in Spain, Sweden, Norway, and Siberia. It also occurs, along with galena and other ores of lead, in the mines of Lead-Hills and Wanlockhead, in Scotland; and in the mines of Cumberland, Northumberland, and Derbyshire; likewise with tin-ore, at Wheal Maudlin, Saint-Just, and other places in Cornwall.

This ore, viewed as a metallurgic object, is one of the most interesting and valuable that is known; it affords natural steel with the greatest facility, and accommodates itself best to the Catalan smelting forge. It was owing in a great measure to the peculiar quality of the iron which it produces, that the excellence long remarked in the cutlery of the Tyrol, Styria, and Carinthia, was due. It was called by the older mineralogists *steel ore.*

The carbonate of iron of the coal formation, is the principal ore from which iron is smelted in England and Scotland, and it yields usually from 30 to 33 per cent. of cast metal. We are indebted to Dr. Colquhoun for several elaborate analyses of the sparry-irons of the Glasgow coal field; ores which afford the best qualities of iron made in that district. The richest specimen, out of the nine which he tried, came from the neighborhood of Airdrie; it had a specific gravity of 3·0533, and afforded in 100 parts, carbonic acid, 35·17; protoxyde of iron, 53·03; lime, 3·33; magnesia, 1·77; silica, 1·4; alumina, 0·63; peroxyde of iron, 0·23; carbonaceous or bituminous matter, 3·03; moisture and loss, 1·41. Its contents in metallic iron are 41·25.

The *compact carbonate of iron* has no relation externally with the sparry variety. It comprehends most of the clay-iron stones, and particularly that which occurs in flattened spheroidal masses of various size, among the coal measures. The color of this ore is often a yellowish-brown, reddish-gray, or a dirty brick-red. Its fracture is close grained; it is easily scratched, and gives a yellowish-brown powder. It adheres to the tongue, has an odor slightly argillaceous when breathed upon, makes no effervescence with any acid, blackens at the blow-pipe without melting, and becomes attractable by the magnet with the slightest calcination.

This ore affords from 30 to 40 per cent. of iron of excellent quality; and it is the object of most extensive workings in Great Britain. It occurs in the slaty clay which serves as a roof or floor to the strata of coal; and also in continuous beds, from 2 to 18 inches thick, among the coal measures, as in Staffordshire, Shropshire, and Wales. It is remarkable, that the coal-basin of Newcastle contains little clay iron-stone, while the coal-basin of Dudley is replete with it.

13. *Phosphate of iron.*—A dull blue color is the most remarkable external character of this species, which occurs in small masses composed of aggregated plates, sometimes in an excessively fine powder, or giving other bodies a blue tinge. It assumes at the blowpipe a rusty hue, and is then reduced to a button of a metallic aspect. It dissolves completely in dilute nitric acid, as well as in ammonia, but it does not communicate its color to them, and oil turns it black; characters which distinguish it readily from blue carbonate of copper, whose color is not altered by ammonia. It is of no use as a smelting ore.

14. *Sulphate of iron, native green vitriol.*—This is formed by the oxygenation of sulphuret of iron, and is unimportant in a metallurgic point of view.

15. *Chromate of iron.*—For the treatment and use of this ore, see CHROME.

16. *Arseniate of iron, Wurfelerz.*

17. *Muriate of iron.*

18. *Oxalate of iron; Humboldtite,* found by M. Breithaupt in the lignite of Kolaw. It consists of protoxyde of iron, 53·86; oxalic acid, 46·14; in 100.

19. *Titanate of iron* consists of protoxyde and peroxyde of iron, 86; titanic acid, 8; oxyde of manganese, 2; gangue, 1 = 97. See *Black Oxyde* of iron.

Of the assay of iron-ores by fusion.—In the assays by the dry way, the object is to separate exactly all the iron which the ore may contain, with the view of comparing the result with the product of smelting on the great scale. In order to succeed in this operation, we must deoxydize the iron, and produce at the same time such a temperature as will melt the metal and the earths associated with it in the ore, and obtain the former in a dense button at the bottom of a crucible, and the latter in a lighter glass or slag, above it. Sometimes the gangue of the ores, consisting mostly of a single earth, as quartz, alumina, or lime, is of itself very refractory, and hence some flux must be added to bring about the fusion. The substance most commonly employed for this purpose is borax; but ordinary flint glass may be substituted for it. Sometimes, also, instead of adding borax, which always succeeds, lime or clay may be added to the ore, according to the nature of its mineralizer; that is, lime for a clay iron-stone, and clay for a calcareous carbonate of iron; and both, when the gangue is silicious, as occurs with the black oxyde.

The ore, pulverized and passed through a silk sieve, is to be well mixed with the flux, and the mixture introduced into the smooth concavity made in the centre of a crucible lined with hard-rammed damp charcoal dust. Were the mixture diffused through the charcoal, the reduced iron would be apt to remain scattered in little globules through the crucible, and no metallic button would be formed at its bottom. The mingled ore and flux must be covered with charcoal. The crucible thus filled must be shut with an earthen lid luted on with fire-clay; and it is then set on its base, either in an air furnace, or on the hearth of a forge urged with a smith's bellows. The heat should be very slowly raised, not employing the bellows till three quarters of an hour have expired. In this way, the water of the damp charcoal (*brasque*) is allowed to exhale slowly, and the deoxydation is completed before the fusion begins; for by acting otherwise, the slags formed would dissolve some oxyde of iron, and the assay would not indicate the whole of the iron to be obtained from the ore. At the end of the above period, the fire must be raised progressively to a white heat, at which pitch it must be maintained for a quarter of an hour, after which the crucible should be withdrawn. Whenever it has cooled, it is to be opened, the *brasque* must be carefully removed or put aside, and the button of cast-iron taken out and weighed. The *brasque* may sometimes contain a few globules, which must be collected by washing in water, or the application of a magnetic bar. The quantity of iron denotes, of course, the richness of the ore. These assays furnish always a gray cast-iron; and, therefore, the quality of the products can hardly be judged of, except by an experiment on the large scale. The temperature necessary for the success of an assay is about 150° of Wedgewood.

In the assays by the *humid* way, we may expect to find manganese, silica, alumina, lime, magnesia, and sometimes carbonic acid, associated with the iron. 100 grains of the ore in fine powder are to be digested with nitro-muriatic-acid; which will leave only the silica with perhaps a very little alumina. If an effervescence takes place in the cold with a dilute acid, the loss of weight will indicate the amount of carbonic acid gas expelled. The muriatic solution contains the iron, the manganese, the lime, magnesia, and most of the alumina, with a little silica. On evaporating to dryness, and digesting in water, all the silica will remain in an insoluble state. If the solution somewhat acidulated be treated with oxalate of ammonia, the lime will fall down in the form of an oxalate; ammonia will now precipitate the alumina and the oxyde of iron together, while the manganese and magnesia will continue dissolved in the state of triple salts (ammonia-muriates). The alumina may be separated from the ferric oxyde by potash-ley. The manganese may be thrown down by hydrosulphuret of potash; and, finally, the magnesia may be precipitated by carbonate of soda. 100 parts of the red oxyde of iron contain 69·34 of metal, and 30·66 of oxygen.

If phosphorus be present in the ore, the nitro-muriatic solution, being rendered nearly neutral, will afford with muriate of lime a precipitate of phosphate of lime, soluble in an excess of muriatic acid.

When the sole object is to learn readily the per-centage of iron, the ore may be treated with hot nitro-muriatic, the acid solution filtered and supersaturated with ammonia, which will throw down only the iron oxyde and alumina; because the lime is not precipitable by that alkali, nor is magnesia and manganese, when in the state of ammonia-muriates. The red precipitate, being digested with some potash-ley, will lose its alumina, and will leave the ferric oxyde nearly pure. The presence of sulphur, phosphorus, or arsenic, in iron ores, may always be detected by the blowpipe, or ustulation in the assay muffle, as described under FURNACE.

Of the smelting of iron ores.—We shall describe, in the first place, the methods practised in Great Britain, and shall afterwards consider those pursued in other countries, in the treatment of their peculiar ores.

Iron is divided into three kinds, according to the different metallic states in which it may be obtained; and these are called *crude* or *cast iron; steel;* and *bar* or malleable iron. These states are determined essentially by the different proportions of charcoal or carbon held in chemical combination; cast iron containing more than steel, and steel more than malleable iron; which last, indeed, ought to be the pure metal, a point of perfection, however, rarely if ever attained. It is impossible to assign the limits between these three forms of iron, or their relative proportions of carbon, with ultimate precision; for bar iron passes into steel by insensible gradations, and steel and cast iron make such mutual transitions as to render it difficult to define where the former commences, and the latter ceases, to exist. In fact, some steels may be called crude iron, and some cast irons may be reckoned among steels.

Towards the conclusion of the last century the manufacture of iron underwent a very important revolution in Great Britain, by the substitution of pitcoal for charcoal of wood, the only combustible previously used in smelting the ores of this metal. This improvement served not merely to diminish the cost of reduction, but it furnished a softer cast iron, fit for many new purposes in the arts. From this era, iron works have assumed an immense importance in our national industry, and have given birth to many ingenious and powerful machines for fashioning the metal into bars of every form, with almost incredible economy and expedition.

The profusion of excellent coal, and its association in many localities with iron-stone, have procured hitherto for our country a marked superiority over all others in the iron trade; though now every possible effort is making by foreign policy to rival or to limit our future operations. In 1802, M. de Bonnard, now divisionary inspector in the royal corps of mines of France, and secretary of the general council, made a tour in England, in order to study our new processes of manufacturing iron, and published, on his return, in the Journal des Mines, tom. 17, a memoir descriptive of them. Since the peace, many French engineers and iron-masters have exerted themselves in naturalizing in France this species of industry; and M. de Gallois, in particular, after a long residence in Great Britain, where he was admitted to see deliberately and minutely every department of the iron trade, returned with ample details, and erected at Saint-Etienne a large establishment entirely on the English model. More recently, MM. Dufrénoy and Elie de Beaumont, and MM. Coste and Perdonnet, have published two very copious accounts of their respective metallurgic tours in Great Britain, illustrated with plans and sections of our furnaces, for the instruction of the French nation.

The argillaceous carbonate of iron, or clay iron-stone of the coal measures, is the chief ore smelted in England. Some red hematite is used as an auxiliary in certain works in Cumberland and Lancashire; but nowhere is the iron-sand, or other ferruginous matters of the secondary strata, employed at present for procuring the metal.

Among the numerous coal-basins of England there are two, in particular, which furnish more than three fourths of the whole cast iron produced in the kingdom; namely, the coal field of Dudley, in the south of Staffordshire; and the coal fields of Monmouthshire, in South Wales, along with those of Gloucestershire and Somersetshire.

Dudley is peculiarly favored by nature. There are found associated the coal, the iron ore, the limestone for flux, and the refractory fire-clay for constructing the interior brick-work of the furnaces. This famous clay is mined at Stourbridge, and exported to every part of the kingdom for making cast steel crucibles and glass-house melting pots.

At Merthyr-Tydvil, the centre of the iron-works of Wales, the iron-stone is extremely plentiful, forming 16 beds, or rather constituting an integrant portion of 16 beds of slate-clay. Sometimes it occurs in pretty long tables adjoining each other, so as to resemble a continuous stratum; but more frequently it forms nodules of various size and abundance, placed in planes both above and below the coal seam. Eight varieties of ore, belonging to different beds, have been distinguished by the following barbarous names: black balls, black pins, six-inch-wide vein, six-inch jack, blue vein, blue pins, gray pins, seven pins. The bed containing the first quality of iron-stone is analogous to the black ore of Staffordshire, called *gubbin;* it is often cleft within like *septaria,* and its cavities are sometimes besprinkled with crystals of carbonate of lime or quartz. In the superior beds there are nodules decomposing into concentric coats, of which the middle is clay. Crystals of oxyde of titanium are occasionally found in the middle of the balls of clay iron-stone; to which the metallic titanium observed in the inside of the dome of blast furnaces, may be traced. Both at Dudley and South Wales, casts of shells, belonging to the genus *unio*, are observed on the iron-stone.

The average richness of the iron-stones of South Wales is somewhat greater than that of those of Staffordshire. The former is estimated at 33 parts of cast iron, while the latter rarely exceeds 30 parts in 100 of ore; and this richness, joined to the superior quality of cheapness of the coals, and the proximity of the sea, gives South Wales a decided advantage as a manufacturing district.

The number of blast furnaces in the parish of Merthyr-Tydvil amounts to upwards of 30. The cast iron produced is, however, seldom brought into the market, but is almost entirely converted into bar iron, of which, at Mr. Crawshay's works, 600 tons are manufactured in a week. Numerous iron railways, extending through a length of 220 miles, facilitate the transport of the materials and the exportation of the products. That concurrence of favorable circumstances, which we have noticed as occurring at Dudley, prevails in an equal degree in South Wales.

The same economy which the use of coal has introduced into the smelting of cast iron from the ore, also extends to its refinery into bars. And this process would supersede in every iron work the use of wood charcoal, were not the iron produced by the latter combustible better for many purposes, particularly the manufacture of steel. In some English smelting works, indeed, where sheet iron is prepared for making tin plate, a mixed refining process is employed, where the cast iron is made into bar iron by wood charcoal, and laminated by the aid of a coal fire.

Till 1740, the smelting of iron ores in England was executed entirely with wood charcoal; and the ores employed were principally brown and red hematites. Earthy iron ores were also smelted; but it does not appear that the clay iron-stones of the coal-basins were then used, though they constitute almost the sole smelting material at the present day. At that era, there were 59 blast furnaces, whose annual product was 17,350 tons of cast iron; that is, for each furnace, 294 tons per annum, and 5⅝ tons per week. By the year 1788, several attempts had been made to reduce iron ore with coked coal; and there remained only 24 charcoal blast furnaces, which produced altogether 13,000 tons of cast iron in the year; being at the rate of 546 tons for each per annum, or nearly 11 tons per week. This remarkable increase of 11 tons for 5⅛, was due chiefly to the substitution of cylinder blowing machines worked with pistons, for the common wooden bellows. Already 53 blast furnaces fired with coke were in activity; which furnished *in toto* 48,800 tons of iron in a year; which raises the annual product of each furnace to 907 tons, and the weekly product to about 17½ tons. The quantity of cast iron produced

that year (1788) by means of coal, was - - - - - - - -	48,800 tons,
and that by wood charcoal, was - - - - - - - -	13,100
Constituting a total quantity of - - - - - - -	61,900 tons.

In 1796, the wood charcoal process was almost entirely given up; when the returns of the iron trade made by desire of Mr. Pitt, for establishing taxes on the manufacture afforded the following results:—

121 blast furnaces, furnishing in whole per annum 124,879 tons, constituting an average amount for each furnace of 1032 tons.

In 1802, Great Britain possessed 168 blast furnaces, yielding a product of about 170,000 tons; and this product amounted, in 1806, to 250,000 tons, derived from 227 coke furnaces, of which only 159 were in activity at once. These blast furnaces were distributed as follows.

In the principality of Wales - - - - - - - - - -	52
In Staffordshire - - - - - - - - - - - - - -	42
In Shropshire - - - - - - - - - - - - - -	42
In Derbyshire - - - - - - - - - - - - - -	17
In Yorkshire - - - - - - - - - - - - - -	28
In the counties of Gloucester, Monmouth, Leicester, Lancaster, Cumberland, and Northumberland - - - - - - - - - -	18
In Scotland - - - - - - - - - - - - - -	28
	227

In 1820, the iron trade had risen to the amount shown in the following table:—

	Tons.
Wales manufactured, per annum - - - - - - - - -	150,000
Shropshire and Staffordshire - - - - - - - - -	180,000
Yorkshire and Derbyshire - - - - - - - - -	50,000
Scotland, with some places in England - - - - - -	20,000
Total - - - - - - -	400 000

In a statistical view given by M. de Villefosse, of the French and English iron works he assigns to the latter, in 1826, 305 blast furnaces, distributed as follows:—

In the principality of Wales	87
In Staffordshire	78
In Shropshire, Derbyshire, Yorkshire, &c.	84
In Scotland	56
	305

Out of these, 280 were in activity at the same time; and if we suppose their mean product to have been 50 tons a week, the total product would have been, in 1826, 728,000 tons. But this estimate seems to be somewhat above the truth; for, from the information communicated by Mr. Philip Taylor to M. Achille Chaper, a considerable French iron master, who, in the summer of 1826, inspected two thirds of the blast furnaces of Great Britain, their product during this year was about 600,000 tons.

The preceding details show the successive increments which the manufacture of cast iron has received; and a similar progression has taken place in its refinery into wrought iron. This operation was formerly effected by the agency of wood charcoal in refineries analogous to those still made use of in France. But when that kind of fuel began to be scarce in this island, it came to be mixed with coke in various proportions. The bar iron thus produced was usually hard, and required much time to convert, so that an establishment which could produce 20 tons of bar iron in a week, was deemed considerable. At that time, England imported annually from Sweden and Russia the enormous quantity of 70,000 tons of iron.

Mr. Cort, to whom Great Britain is indebted for the methods now pursued in this country, succeeded about that time, after many unsuccessful experiments, in converting cast iron into bar iron, by exposing it on the hearth of a reverberatory furnace to the flame of pitcoal. This method, which possessed the advantage of employing this species of combustible alone, likewise simplified the treatment, because it required no blast apparatus. But this mode of refinery, consisting in the use of a reverberatory furnace alone, did not produce altogether the desired result. It was irregular; sometimes the loss of iron was small, but at others it was very considerable; and there were great variations in the quality of the iron, as well as in the quantity of fuel consumed. Mr. Cort succeeded in removing this uncertainty of result, by causing the puddling in the reverberatory furnace to be preceded by a kind of refinery with coke. The intent of this operation was to decarburate the iron, and to prepare it for becoming malleable. The metal took in that case the name of *finery* metal, called, for the sake of brevity, *fine-metal.*

He also substituted the drawing cylinders for the extension under the hammer, an improvement which accelerated greatly the manufacture of bar iron. The iron then yielded by the operation of puddling was of a very inferior quality, and could not be directly employed in the arts. In order to give it more consistence, it was subjected to a second heating in a reverberatory furnace; and whenever this method had arrived at a high enough degree of perfection to afford products fit for the market, it became exclusively employed in Great Britain. This new method of transforming cast iron into malleable iron speedily gained such an extension, that of late years, a single iron-work, Cyfartha in Wales, manufactured annually more than twice as much as was made annually from 1740 to 1750, in the whole kingdom.

In surveying the improvements which the iron manufacture has received in England in the space of the last 60 years, they are seen to be resolvable into two; the first set relating to the smelting of the ores; the other, to the conversion of the pigs into bar iron; hence naturally arise two heads under which the subject of iron must be treated.

1. *Manufacture of cast-iron by coke and coal.*—The cast-iron produced by the English and Scotch blast furnaces is in general black and very soft; but yet may be distinguished into several qualities, of which three are particularly noticed.

No. 1. *Very black cast-iron,* in large rounded grains, obtained commonly near the commencement of the casting, when an excess of carbon is present; in flowing, it appears pasty, and throws out blue scintillations. It exhibits a surface where crystalline vegetations develop themselves rapidly in very fine branches; it congeals or fixes very slowly; its surface when cold is smooth, concave, and often charged with plumbago; it has but a moderate tenacity, is tender under the file, and susceptible of a dull polish. When melted over again, it passes into No. 2, and forms the best castings.

No. 2. *Black cast-iron* has a somewhat lighter shade than the preceding, and may therefore on comparison be called blackish-gray. It presents less large granulations than No. 1; is tenacious, easily turned, filed, and polished; excellent for casting when it approaches to No. 1, and for the manufacture of bar iron when it has on the contrary a shade somewhat lighter. If repeatedly melted, it passes into the next quality, or

No. 3. *White cast iron;* this is brittle, and indicates always some derangement in the working of the furnace; it flows imperfectly, and darts out, in casting, abundance of brilliant white scintillations; it fixes very quickly; and on cooling, exhibits on its surface irregular asperities, which make it extremely rough. It is easily broken, and presents a lamellar and radiated fracture; and is so hard that tempered steel cannot act upon it. It is cast only into weights, bullets, or bombs, but never into pieces of machinery. When exposed to the refinery processes, it affords a bad bar iron. It is owing probably to the different nature of the cast iron obtained in different counties in England, that Staffordshire and Shropshire furnish the greater part of the great iron castings, while Wales manufactures almost exclusively malleable iron. The lower price of coals in Wales is perhaps the cause to a certain extent of this difference in the results of these two iron districts. It will be interesting, at any rate, to describe separately the processes employed in Staffordshire and Wales.

The blast furnaces of Staffordshire, in the neighborhood of Dudley, Bilston, and Wednesbury, are constructed almost wholly of bricks. Their outer form is frequently a cone, often also a pyramid with a square base. They are bound about with a great many iron hoops, or with iron bars placed at different heights. This powerful armor allows the furnaces to be built much less massively than they formerly were; and admits lighter and more elegant external forms. They are seldom insulated; but are usually associated to the number of two or three in the same line. A narrow passage is left between them, which leads to the lateral openings where the tuyères are placed. At the front of the furnace, a large shed is always raised. The roofs of these sheds present in general circular profiles, and being made of cast or bar iron, they display a remarkable lightness of construction. The cast iron columns likewise, which support the joists and girders, give additional elegance.

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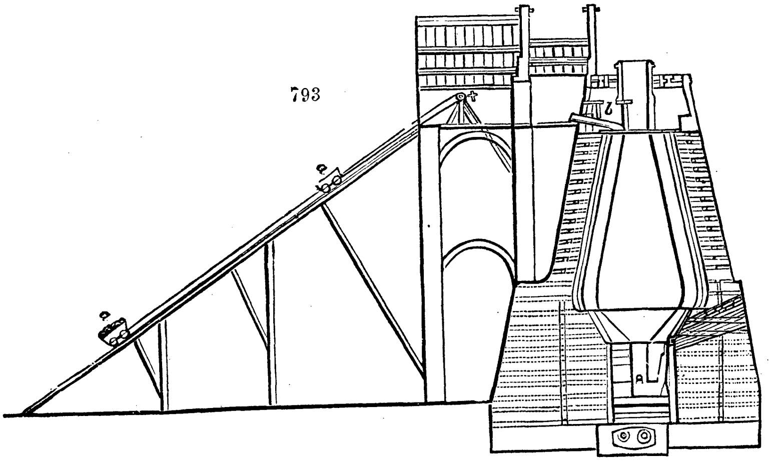

In the Dudley field, the furnaces are almost always in the middle of the plain, and an inclined rail-way must be formed to reach their platform. These inclined planes, composed of beams or rails placed alongside of each other, and sustained by props and cross-bars, as indicated in *fig.* 793, are set up mostly against the posterior face of the furnace. Two chains or ropes, passing over the drums of gins, moved by a steam engine (commonly the same that drives the bellows), draw up the wagons of wood or sheet iron *a a*, which contain the various materials for supplying the furnace. To facilitate this service, the platform round the furnace is sometimes enlarged behind by a floor; while a balustrade, which opens when the wagons arrive at the platform, prevents accidents. This projection is occasionally covered by a roof. For a furnace of the largest size, the force expended by this lifting apparatus is not more than a two-horse power.

Fig. 793 is a vertical section through the furnace from front to rear, or at right angles to the line of the lateral tuyères. The erection of a pair of blast furnaces, of 40 feet high each, costs, in the Dudley district, 1800 pounds sterling; and requires for building each, 160,000 common bricks for the outside work, 3900 fire-bricks for the lining or shirt of the furnace, and 825 for the boshes. The dimensions of the fire-bricks are various; 5 kinds are employed for the lining, and 9 kinds for the boshes. They are all 6 inches thick, and are curved to suit the *voussoirs*.

The number of charges given in 12 hours is different in different furnaces; being sometimes 20, 25, and even so high as 40; but 30 is a fair average. Each charge is composed of from 5 to 6 cwts. of coke, (or now of 3 to 4 cwts. of coal with the hot **blast**); 3, 4, and sometimes 6 cwts. of the roasted mine, according to its richness and the quality of cast iron wanted; the limestone flux is usually one third of the weight of the roasted iron stone. There are 2 casts in 24 hours; one at 6 in the morning, and another at 6 in the evening.

The height of the blast furnaces is very variable; some being only 36 feet high including the chimney, while others have an elevation of 60 feet. These extreme limits are very rare: so that the greater part of the furnaces are from 45 to 50 feet high. They are all terminated by a cylindrical chimney of from 8 to 12 feet long; being about one fifth of the total height of the furnace. The inside diameter of this chimney is the same as that of the throat or mouth; and varies from 4 to 6 feet. The chimney is frequently formed of a single course of bricks, and acquires solidity from its hoops of iron, so thickly placed that one half of the surface is often covered with them. At its lower end, the mouth presents one or two rectangular openings, through which the charge is given. It is built on a basement circle of cast-iron, which forms the circumference of the throat; and a sloping plate of cast-iron *b* is so placed as to make the materials slide over into the furnace, as shown in the figure.

The inside of the blast furnaces of Staffordshire is most frequently of a circular form, except the hearth and working area. The inner space is divided into four portions, different in their forms, and the functions which they fulfil in the smelting of the ore.

The undermost, called the hearth, or crucible, in which the cast-iron collects, is a right rectangular prism, elongated in a line prependicular to the axes of the tuyères. The sides of the hearth consist in general of refractory sandstone (fire-stone), obtained mostly from the bed of the coal basin, called *millstone grit;* and the bottom of the hearth is formed of a large block of the same nature, laid on a cast-iron plate.

The second portion is also made of the same refractory grit stone. It has the form of quadrangular pyramidal, approaching considerably to a prism, from the smallness of the angle included between the sides and the axis.

The third portion or lower body of the furnace is conical, but here the interior space suddenly expands; the slope outwards at this part seems to have a great influence on the quality of the cast-iron obtained from the furnace. When No. 2 of the blackest kind is wanted for castings, the inclination of this cavity of the furnace is in general less considerable than when No. 2 cast iron for conversion into bar iron is required. The inclination of this conical chamber, called the boshes, varies from 55 to 60 degrees with the horizon. The diameter of this part is equal to that of the belly, and is from 11 to 13 feet. The boshes are built of masonry, as shown in *figs.* 794, 795.

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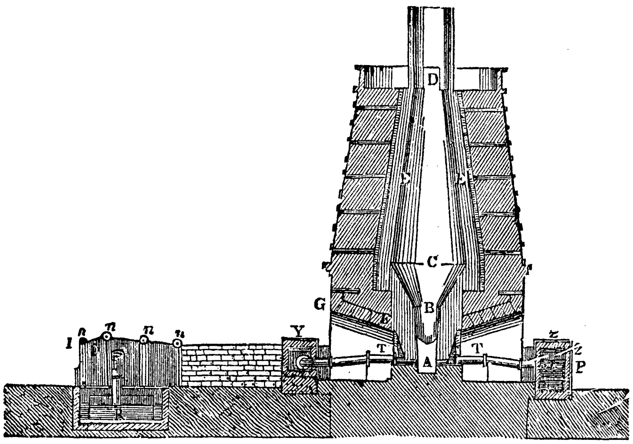

The fourth part, which constitutes about two thirds of the height of the furnace from the base of the hearth up to the throat, presents the figure of a surface of revolution, generated by a curve whose concavity is turned towards the axis of the furnace, and whose last tangent towards the bottom is almost vertical. This surface is sloped off with that of the boshes (*étalages* in French), so that no sharp angle may exist at the belly. In some furnaces of considerable dimensions, as in that with three tuyères, this portion of the furnace is cylindrical for a certain height.

The following measurements represent the interior structure of two well-going furnaces.

	No. 1.	No. 2.
	Feet.	*Feet.*
Height from the hearth to the throat or mouth - -	45	49
Height of the crucible or hearth - - - -	6½	6
— of the boshes - - - - - - -	8	7
— of the cone - - - - - - -	30½	36
— of the chimney or mouth - - - - -	8	12¾
Width of the bottom of the hearth - - - -	2½	2
Ditto at its upper end - - - - - -	3	2⅔
Ditto of the boshes - - - - - - -	12⅔	13½
Ditto at one third of the belly - - - - -	12	11½
Ditto at two thirds of ditto - - - - -	8⅔	9½
Ditto at the mouth - - - - - - -	4½	3⅔
Inclination of the boshes - - - - -	59°	52°

The conical orifice called the tuyère, in which the tapered pipes are placed, for imparting the blast, is seen near the bottom of the furnace, *fig.* 794, at A. Nose tubes of various sizes, from 2 to 4 inches in diameter, are applied to the extremity of the main blast-pipe. Under A is the bottom of the hearth, which, in large furnaces, may be two feet square. B is the top of the hearth, about two feet six inches square. A B is the height of the hearth, about six feet six inches. B shows the round bottom of the conical or funnel part, called in this country the *boshes*, standing upon the square area of the hearth. C is the top of the boshes, which may be about 12 feet in diameter, and 8 feet in perpendicular height. D is the furnace top or mouth (*gueulard* in French), at which the *materials are charged.* It may be 4½ feet in diameter. The line between C, D, is the height of the internal cavity of the furnace, from the top of the boshes upwards, supposed to be 30 feet. A, D, is the total height of the interior of the furnace, reckoned at 44½ feet. E E is the lining, which is built in the nicest manner with the best fire-bricks, from 12 to 14 inches long, 3 inches thick, and curved to suit the circle of the cone. A vacancy of 3 inches wide is left all round the outside of the first lining by the builder; which is sometimes filled with coke dust, but more generally with sand firmly rammed. This void space in the brick-work is for the purpose of allowing for any expansion which might occur, either by an increase in the bulk of the building, or by the pressure and weight of the materials when descending to the bottom of the furnace. Exterior to E E is a second lining of fire-bricks similar to the first. At F, on either side, is a cast-iron lintel, 8½ feet long, by 10 inches square, upon which the bottom of the arches is supported. F, G, is the rise of the tuyère arch, which may be 14 feet high upon the outside, and 18 feet wide. The extreme size of the bottom or sole of the hearth, upon each side of A, may be 10 feet square. This part and the boshing stones are preferably made from a coarse sandstone grit, containing large rounded grains of quartz, united by a siliceo-argillaceous cement.

The bottom of the hearth consists, first, of a course of the said gritstone; beneath which is a layer of bedding sand, having, in its under part, passages for the escape of the vapors generated by damps; the whole being supported upon pillars of brick.

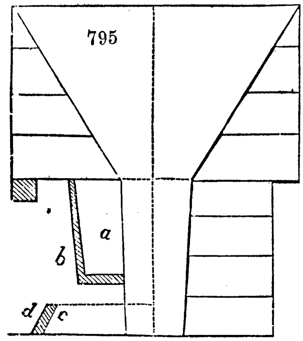

Fig. 795 represents the hearth and boshes, in a vertical side section. *a* is the tymp stone, and *b* the tymp plate for confining the liquid metal in the hearth. The latter is wedged firmly into the side-walls of the hearth; *c* is the dam-stone, which occupies the whole breadth at the bottom of the hearth, excepting about 6 inches, which space, when the furnace is at work, is filled, before every cast, with a strong binding sand. This stone is faced outside by a cast-iron plate *d*, called the dam-plate, of considerable thickness, and peculiar shape. The top of the dam-stone, or rather the notch of the dam-plate, lies from 4 to 8 inches under the level of the tuyère hole. The space under the tymp plate, for 5 or 6 inches down, is rammed full, for every cast, with strong loamy earth, or even fine clay; a process called the tymp stopping. The area of the base of this furnace being 38 feet, its extreme height is 55 feet.

The blast furnaces of Staffordshire have always two tuyères, at least, placed on opposite sides, but so pointed that the blast may not pursue directly opposite lines. In a furnace acting well in the neighborhood of Dudley, the one of the tuyères was 10 inches distant from the posterior wall of the hearth, and the other only four inches. In other furnaces with 3 tuyères, the side ones are placed, the one 16½ inches, and the other 6½ inches from the back. Three tuyères are seldom made to blow simultaneously. The third is brought into action only when the furnace seems to be choked up, and when it becomes necessary to clear it up by a powerful concussion. Too much pains cannot be bestowed on the masonry and brickwork of a blast furnace, and on the solidity of its foundation. In a soft ground it should rest on piles, so driven that the channel left beneath for the drainage of the building may be above any water level. Small passages should likewise be left throughout the body of the work, for the transpiration of moisture.

The blowing machines employed in Staffordshire are generally cast-iron cylinders, in which a metallic piston is exactly fitted as for a steam engine, and made in the same way. Towards the top and bottom of the blowing cylinders orifices are left covered with valves, which open inside when the vacuum is made with the cylinders, and afterwards shut by their own weight. Adjutages conduct into the iron globe or chest, the air expelled by the piston, both in its ascent and descent; because these blowing machines have always a double stroke.

The pressure of the air is made to vary through a very considerable range, according to the nature of the fuel and season of the year; for as in summer the atmosphere is more rarefied, it must be expelled with a compensating force. The limits are from 1½ pounds to 3½ pounds on the inch; but these numbers represent extreme proportions, the average amount in Staffordshire being 3 pounds. With this pressure a furnace usually works, which affords 60 tons of cast-iron in the week; and the pressure may be 2½ pounds on an average. The orifices, or nose-pipes, through which the air issues, also vary with the nature of the coke and the ore. In Staffordshire they are generally from 2 inches and 5 tenths to 2 inches and 8 tenths in diameter.

The blowing machines of Staffordshire are always impelled by steam engines. At Mr. Bagnall's works, two blast furnaces, 40 feet high, exclusive of the chimney or top, and two finery furnaces, are worked by a steam engine of 40 horses power; and therefore the power of one horse corresponds to the production of 2½ tons of cast iron per week, independently of the finery.

In South Wales, especially at Pontypool, there are slighter blast furnaces, whose upper portion is composed of a single range of bricks, each of which is 20 inches long, 4 thick, and 9 broad. The interior of the chimney represents an inverted cone.' These furnaces derive solidity, and power to resist the expansions and contractions from change of temperature, by being cased, as it were, in horizontal hoops, placed 3 feet, or, even in some cases, only 6 inches asunder. These flat rings consist of four pieces, which are joined by means of vertical bars, that carry a species of ears or rings, into which the hoops enter, and are retained by bolts or keys. Instead of these ears, screw nuts are also employed for the junction. Each hoop is alternately connected to each of the eight vertical bars. The interior of these furnaces is the same as of the others; being generally from 12 to 14 feet diameter at the belly, and from 50 to 55 feet high. Though slight, they last as long as those composed of an outer body of masonry and a double lining of bricks; and have continued constantly at work for three years. In Wales also the blast furnaces are generally somewhat larger than in Staffordshire; because there the object being to refine the cast iron, they wish to procure as large a smelting product as possible. But in Staffordshire, a fine quality of casting iron is chiefly sought after, and hence their furnaces have less height, but nearly the same width.

In a blast apparatus employed at the Cyfartha works, moved by a 90 horse steam power, the piston rod of the blowing cylinder is connected by a parallelogram mechanism with the opposite end of the working beam of the steam engine. The cylinder is 9 feet 4 inches diameter, and 8 feet 4 inches high. The piston has a stroke 8 feet long, and it rises 13 times in the minute. By calculating the sum of the spaces percurred by the piston in a minute, and supposing that the volume of the air expelled is equal to only 96 per cent. of that sum, which must be admitted to hold with machines executed with so much precision, we find that 12,588 cubic feet of air are propelled every minute. Hence a horse power applied to blowing machines of this nature gives, on an average, 137 cubic feet of air per minute. The pressure on the air, as it issues, rarely exceeds two pounds on the square inch in the Welsh works.

At the establishment of Cyfartha, for blowing seven smelting furnaces, and the seven corresponding fineries, three steam engines are employed, one of 90 horse power, another of 80, and a third of 40; which constitutes in the whole a force of 210 horses, or 26 horses and ⅕ *per furnace*, supposing the fineries to consume one eighth of the blast. In the whole of the works of Messrs. Crawshay, the proprietors of Cyfartha, the power of about 350 horses is expended in blowing 12 smelting furnaces, and their subordinate fineries; which gives from 25 to 26 horses for each, allowing as before one eighth for the fineries. As these furnaces produce each about 60 tons of cast iron weekly, we find that a horse power corresponds to 2 tons and a tenth in that time. Each of the furnaces consumes about 3567 cubic feet of air per minute. These works have been greatly increased of late years.

The following analyses of the English coal ironstones have been made by M. Berthier, at the school of mines in Paris.

——	Rich Welsh Ore.	Poor Welsh Ore.	Rich Ore of Dudley, or *gubbin*.
Loss by ignition - - -	30·00	27·00	31·00
Insoluble residuum - -	8·40	22·03	7·66
Lime - - - - - -	0·0	6·00	2·66
Peroxyde of iron - - -	60·00	42·66	58·33

On calculating the quantities of carbonate of iron, and metallic iron, to which the above peroxyde corresponds, we have:—

Carbonate of iron - -	88·77	65·09	85·20
Metallic iron - - -	42·15	31·38	40·45

The mean richness of the ores of carbonate of iron of these coal basins is not far from 33 per cent. About 28 *per cent.* is dissipated on an average, in the roasting of the ores.

Every ferruginous clay-stone is regarded as an iron ore, when it contains more than 20 per cent. of metal; and it is paid for according to its quality, being on an average at 12 shillings per ton in Staffordshire. The gubbin, however, fetches so high a price as 16 or 17 shillings. The ore must be roasted before it is fit for the blast furnace, a process carried on in the open air. A heap of ore mingled with small coal (if necessary) is piled up over a stratum of larger pieces of coal; and this heap may be 6 or 7 feet high, by 15 or 20 broad. The fire is applied at the windward end, and after it has burned a certain way, the heap is prolonged at the other extremity, as far as the nature of the ground or convenience of the work requires. The quantity of coal requisite for roasting the ore varies from one to four hundred weight per ton, according to the proportion of bituminous matter associated with the iron-stone. The ore loses in this operation from 25 to 30 per cent. of its weight. Three and a quarter tons of crude ore, or two and a quarter tons of roasted ore, are required to produce a ton of cast-iron; that is to say, the crude material yields on an average 30·7 per cent., and the roasted ore 44·4 of pig metal. In most smelting works in Staffordshire, about equal weights of the rich ore in round nodules called *gubbin*, and the poorer ore in cakes called *blue flat*, are employed together in their roasted state; but the proportions are varied, in order to have a uniform mixture, capable of yielding from 30 to 33 per cent. of metal.

The transition or carboniferous limestone of Dudley is used as the flux; it is compact and contains little clay. The bulk of the flux is made nearly equal to that of the ore. To treat two tons and a quarter of roasted ore, which furnish one ton of pig iron, 19 hundred weight of limestone are employed; constituting nearly 1 of limestone for 3 of unroasted ore. The limestone costs 6 shillings the ton.

Carbonized pitcoal or coke was, till within these few years, the sole combustible used in the blast furnaces of Staffordshire.

The coal is distributed in circular heaps, about 5 feet diameter, by 4 feet high; and the middle is occupied by a low brick chimney, piled with loose bricks, so open as to leave interstices between them, especially near the ground. The larger lumps of coal are arranged round this chimney, and the smaller towards the circumference of the heap. When every thing is adjusted, a kindling of coals is introduced into the bottom of the brick chimney; and to render the combustion slow, the whole is covered over with a coat of coal dross, the chimney being loosely closed with a slab of any kind. Openings are occasionally made in the crust and afterwards shut up, to quicken and retard the ignition at pleasure, during its continuance of 24 hours. Whenever the carbonization has reached the proper point for forming good coke, the covering of coal dross is removed, and water is thrown on the heap to extinguish the combustion; a circumstance deemed useful to the quality of the coke. In this operation the Staffordshire coal loses the half of its weight, or two tons of coal produce one of coke.

As soon as the blast furnace gets into a regular heat, which happens about 15 days or three weeks after fires have been put in it, the working consists simply in charging it, at the opening in the throat, whenever there is a sufficient empty space; the only rule being to keep the furnace always full. The coke is measured in a basket, thirteen of which go to the ton. The ore and the flux (limestone) are brought forwards in wheelbarrows of sheet iron. In 24 hours, there are thrown into a furnace such as *fig.* 582, 14⅓ tons of coke, 16 tons of roasted ore, and 6¾ tons of limestone; from which about 7 tons of pig iron are procured. This is run off every 12 hours; in some works the blast is suspended during the discharge. The metal intended to be converted into bar iron, or to be cast again into moulds, is run into small pigs 3 feet long, and 4 inches diameter; weighing each about 2 hundred weight and a half.

The disorders to which blast furnaces are liable have a tendency always to produce white cast-iron. The color of the slag or scoriæ is the surest test of these derangements, as it indicates the quality of the products. If the furnace is yielding an iron proper for casting into moulds, the slag has a uniform vitrification, and is slightly translucid. When the dose of ore is increased in order to obtain a gray pig iron, fit for fabrication into bars, the slag is opaque, dull, and of a greenish-yellow tint, with blue enamelled zones. Lastly, when the furnace is producing a white metal, the slags are black, glassy, full of bubbles, and emit an odor of sulphureted hydrogen. The scoriæ from a coke are much more loaded with lime than those from a charcoal blast furnace. This excess of lime appears adapted to absorb and carry off the sulphur, which would otherwise injure the quality of the iron. The slags, when breathed on, emit an argillaceous odor.

A blast furnace of 50 or 60 feet in height gives commonly from 60 to 70 tons of cast-iron per week; one from 50 to 55 feet high, gives 60 tons; two united of 45 feet produce together 100 tons; and one of 36 feet furnishes from 30 to 40. A blast furnace should go for four or five years without needing restoration. From 3½ to 4 tons of coal, inclusive of the coal of calcination, are required in Staffordshire to obtain one ton of cast-iron; and the expense in workmen's wages is about 15 shillings on that quantity.

At the Cyfartha works of Messrs. Crawshay in South Wales, the average price of the lithoid carbonate of iron, ready for roasting, is only 7*s.* 6*d.* a ton, and its richness is about 33 *per cent.* The furnaces for roasting the ore in that country are made in the form of cylinders, placed above an inverted cone. The cylindrical part is 6 feet high and wide, and the cone is about 4 feet high, with a base equal to that of the cylinder; towards the bottom or narrowest part of the inverted cone, there is an aperture which terminates in an outlet on a level with the bottom of the terrace in which the furnace is built. Sometimes, however, all the roasting furnaces are in a manner combined into one, which resembles a long pit about 6 feet in width and depth, and whose bottom presents a series of inverted hollow quadrangular pyramids, 6 feet in each side, and 4 deep. The bottom or apex of each of these pyramids communicates with a mouth or door-way that opens on a lower terrace, through which the ore falls in proportion as it is roasted; and whence it is wheeled and tumbled into the throat of an adjoining blast furnace, on the same level with the terrace; for in Wales the blast furnace is generally built up against the face of a hill, which makes one of its fronts. The above roasting furnaces, which closely resemble lime-kilns, after being filled with alternate strata of small coal and ore, are set on fire; and the roasted ore is progressively withdrawn below, as already mentioned.

The product of coke from a certain weight of coal is greater in Wales than in Staffordshire, though the mode of manufacture is the same. At Pen-y-Darran, for example, 5 of coal furnish 3½ of coke; or 100 give 70; at Dowlais 100 of coal afford 71 of coke, and the product would be still greater if more pains were bestowed upon the process. At Dowlais, coal costs only 2 shillings a ton; at Cyfartha, it is worth from 2*s.* 6*d.* to 5 shillings. About 2 tons of coke are employed in obtaining 1 ton of cast-iron.

According to M. Berthier's analysis, the slag or cinder of Dowlais consists of silica, 40·4; lime, 38·4; magnesia, 5·2; alumina, 11·2; protoxyde of iron, 3·8; and a trace of sulphur. He says that the silica contains as much oxygen as all the other bases united; or is equivalent to them in saturating power; and to the excess of lime he ascribes the freedom from sulphur, and the good quality of the iron produced. The specimen examined was from a furnace at Merthyr-Tydvil. Other slags from the same furnace, and one from Dudley, furnished upwards of 2 *per cent.* of manganese. Those which he analyzed from Saint Etienne, in France, afforded about 1 per cent. of sulphur.

The consumption of coal in the Welsh smelting furnaces may be estimated, on an average, at 3 tons per ton of cast-iron; corresponding to 2·1 of their coke. From this economy in the quantity of fuel, as well as from its cheapness and that of the iron ore, the iron of South Wales can be brought into the market at a much lower rate than that of any other district. These blast furnaces remain in action from 5 to 10 years; at the end of which time, only their interior surface has to be repaired. The lining of the upper part lasts much longer; for examples are not wanting of its holding good for nearly 40 years.

One of the greatest improvements ever made by simple means in any manufacture is the employment of hot air, instead of the ordinary cold air of the atmosphere, in supplying the blast of furnaces for smelting and founding iron. The discovery of the superior power of a hot over a cold blast in fusing refractory lumps of cast-iron was accidentally observed by my pupil, Mr. James Beaumont Neilson, engineer to the Glasgow gas works, about the year 1827, at a smith's forge in that city, and it was made the subject of a patent in the month of September of the following year. No particular construction of apparatus was described by the inventor by which the air was to be heated, and conveyed to the furnace; but it was merely stated that the air may be heated in a chamber or closed vessel, having a fire under it, or in a vessel connected in any convenient manner with the forge or furnace. From this vessel the air is to be forced by means of bellows into the furnace. The quantity of surface which a heating furnace is required to have for a forge, is about 1260 cubic inches; for a cupola furnace, about 10,000 cubic inches. The vessel may be enclosed in brickwork, or fixed in any other manner that may be found desirable, the application of heated air in any way to furnaces or forges, for the purposes of working iron, being the subject claimed as constituting the invention.

Wherever a forced stream of air is employed for combustion, the resulting temperature must evidently be impaired by the coldness of the air injected upon the fuel. The heat developed in combustion is distributed into three portions; one is communicated to the remaining fuel, another is communicated to the azote of the atmosphere, and to the volatile products of combustion, and a third to the iron and fluxes, or other surrounding matter to be afterwards dissipated by wider diffusion. This inevitable distribution takes place in such a way, that there is a nearly equal temperature over the whole extent of a fire-place, in which an equal degree of combustion exists.

We thus perceive that if the air and the coal be very cold, the portions of heat absorbed by them might be very considerable, and sufficient to preven the resulting temperature from rising to a proper pitch; but if they were very hot they would absorb less caloric, and would leave more to elevate the common temperature. Let us suppose two furnaces charged with burning fuel, into one of which cold air is blown, and into the other hot air, in the same quantity. In the same time, nearly equal quantities of fuel will be consumed with a nearly equal production of heat; but notwithstanding of this, there will not be the same degree of heat in the two furnaces, for the one which receives the hot air will be hotter by all the excess of heat in its air above that of the other, since the former air adds to the heat while the latter abstracts from it. Nor are we to imagine that by injecting a little more cold air into the one furnace, we can raise its temperature to that of the other. With more air indeed we should burn more coals in the same time, and we should produce a greater quantity of heat, but this heat being diffused proportionally among more considerable masses of matter, would not produce a greater temperature; we should have a larger space heated, but not a greater intensity of heat in the same space.

Thus, according to the physical principles of the production and distribution of heat, fires fed with hot air should, with the same fuel, rise to a higher pitch of temperature than fires fed with common cold air. This consequence is independent of the masses, being as true for a small stove which burns only an ounce of charcoal in a minute, as for a furnace which burns a hundred weight; but the excess of temperature produced by hot air cannot be the same in small fires as in great; because the waste of heat is usually less the more fuel is burned.

This principle may be rendered still more evident by a numerical illustration. Let us take, for example, a blast furnace, into which 600 cubic feet of air are blown per minute; suppose it to contain no ore, but merely coal or coke, and that it has been burning long enough to have arrived at the equilibrium of temperature, and let us see what excess of temperature it would have if blown with air of 300° C. (572° F.), instead of being blown with air at 0° C.

600 cubic feet of air under the mean temperature and pressure, weigh a little more than 45 pounds avoirdupois; they contain 10·4 pounds of oxygen, which would burn very nearly 4 pounds of carbon, and disengage 16,000 times as much heat as would raise by one degree Cent. the temperature of two pounds of water. These 16,000 portions of heat, produced every minute, will replace 16,000 other portions of heat, dissipated by the sides of the furnace, and employed in heating the gases which escape from its mouth. This must take place in order to establish the assumed equilibrium of caloric.

If the 45 pounds of air be heated beforehand up to 300° C., they will contain about the eighth part of the heat of the 16,000 disengaged by the combustion, and there will be therefore in the same space one eighth of heat more, which will be ready to operate upon any bodies within its range, and to heat them one eighth more. Thus the blast of 300° C. gives a temperature which is nine eighths of the blast at zero C., or at even the ordinary atmospheric temperature; and as we may reckon at from 2200° to 2700° F. (from 1200° to 1500° C.), the temperature of blast furnaces worked in the common way we perceive that the hot air blast produces an increase of temperature equal to from 270° to 360° F.

Now in order to appreciate the immense effects which this excess of temperature may produce in metallurgic operations, we must consider that often only a few degrees more temperature are required to modify the state of a fusible body, or to determine the play of affinities dormant at lower degrees of heat. Water is solid at 1° under 32° F.; it is liquid at 1° above. Every fusible body has a determinate melting point, a very few degrees above which it is quite fluid, though it may be pasty below it. The same observation applies to ordinary chemical affinities; charcoal, for example, which reduces the greater part of metallic oxydes, begins to do so only at a determinate pitch of temperature, under which it is inoperative, but a few degrees above, it is in general lively and complete. It is unnecessary, in this article, to enter into any more details to show the influence of a few degrees of heat, more or less, in a furnace, upon chemical operations, or merely upon physical changes of state.

These consequences might have been deduced long ago, and industry might thus have been enriched with a new application of science; but philosophers have been and still

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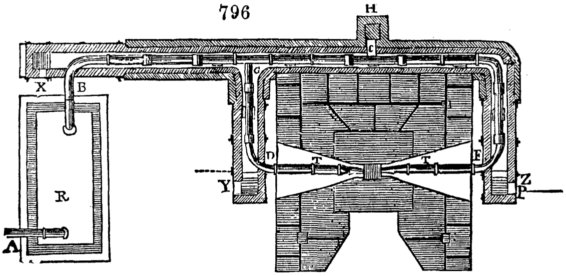

are too much estranged from the study of the useful arts, and content themselves too much with the minutiæ of the laboratory or theoretic abstractions. Within the space of 7 years, the use of the hot blast has been so much extended in Great Britain, as to have enabled many proprietors of iron works to add 50 per cent. to their weekly production of metal, to diminish the expenses of smelting by 50 per cent., and, in many cases, to produce a better sort of cast iron from indifferent materials.

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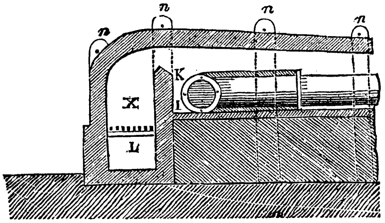

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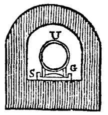

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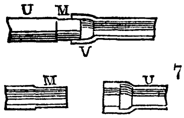

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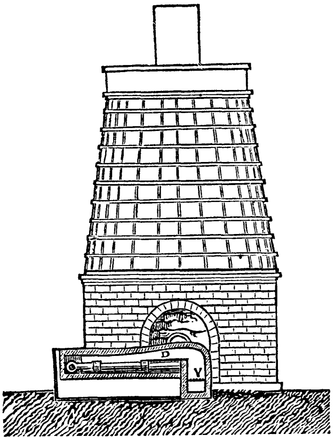


The figures here given represent the blast furnace, and all the details of the air heating, at one view. *Fig.* 794 is a vertical section of the furnace and the apparatus; *fig.* 796 represents the plan at the height of the line 1, 2, of *fig.* 794. The blowing machine, which is not shown in this view, injects the air through the pipe A, into the regulator chamber R, *fig.* 796; the air thence issues by the pipe B, proceeds to C, where it is subdivided into two portions; the one passes along the pipe C D to get to the tuyère T, the other passes behind the furnace, and arrives at the tuyère T′ by the pipe C E F.

These pipes are distributed in a long furnace or flue, whose bottom, sides, and top are formed with fire-brick, where they are exposed to the action of the flame of the three fires X, Y, Z. The flame of the fire X plays round the pipe B at its entrance into the flue, and quits it only to go into the chimney H; that of the fire Y acts from the point D to the same chimney, passing by the elbow C; that of the fire Z acts equally upon F and H, in passing by the elbow E.

Disposition of the fires and furnace.—*Fig.* 797 represents, upon a scale three times larger than *fig.* 796, the section of the fire x, of which the plan is seen in *fig.* 796, and the elevation in *fig.* 794; as also in the outside view of the blast furnace, *fig.* 800.

The grate is at L; the fuel is introduced by the door P, *fig.* 794; the flame rises above the bridge I K, and proceeds along the vaulted flue towards the chimney H. Through a length of about 13 feet, including the grate, the furnace is on each side supported by oblong plates of cast-iron, which are bound together by 4 upright ribbed or feathered bars, also on each side; these bars, *n*, being bound together by iron rods furnished with screw nuts at their ends (*figs.* 794, 796, 797). Beyond this distance, the outside of the furnace is mere brickwork.

The fires Y and Z have exactly a like disposition with the above.

Fig. 797 indicates the dimensions and the curvature of the arch above the grate, near the bridge; *fig.* 798 represents the section of the furnace and of the pipe beyond the cast-iron casing.

I find that the furnace is only about 3 feet wide at the bottom, and that the elevation of the arch above the bottom is no more than 30 inches. Perhaps it might be made a little wider with advantage; the combustion would be more vigorous and effective; and if the sides also were a little thicker, the heat would be better confined.

The distance from the fire-place X to the chimney H, is 43½ feet.
— — Y to the point C, is 13 —
— — Z to the chimney, is 29 — including the turn of the elbow E.

Distribution of the pipes.—At B the pipe is 18 inches diameter outside, and one inch thick of metal, and it tapers to C; from C to D and from D to C the pipes are only 11 inches in external diameter, and three fourths of an inch thick; they are 5 feet long, and are united by two kinds of joints; the ordinary ones, and those of compensation, to give play for the expansion and contraction. One of these is seen between B and C, one between C and D, one between C and E, and a fourth between E and F. These pipes and their adjustment are seen more at large in *fig.* 799; U V is one of these pipes, its widened mouth receives the extremity M of the preceding pipe. These pieces are truly bored and turned to fit each other, and slide out and in like telescope tubes, by the effect of dilatation and contraction of the pipes with changes of temperature.

At certain distances castors or friction-rollers of cast-iron are placed to carry the pipes, which roll upon oblong plates of cast-iron laid upon the floor of the flues. These castors are shown at *a, b, c, d, e, f, g, fig.* 796; one of them is shown separate upon a larger scale at G, in *fig.* 798, as also the plate or rail S, on which it runs.

The tuyères T T′ are adjusted into the pipe behind them; this is truly bored, so as to allow the thick end of the tuyère to slide tightly backwards and forwards in it, like a piston in the barrel of a pump; a diaphragm moreover prevents the tuyère from being drawn or forced entirely out of its tube. At the side of this tube there is a small orifice, which may be shut or opened at pleasure with a stopcock or screw-plug: it serves to try the degree of heat of the air-blast; if a lead wire does not melt when held at this hole, the temperature is reckoned too low; being under the 612th degree of Fahrenheit. The nozzles are 2 inches in diameter.

Near the fire-places of the air-heating furnaces the pipes are at a cherry-red heat; and lest they should be burned, they are there coated with a lute of fire-clay, as shown near K, in *fig.* 797. By this means the air is kept up at the heat of 350° C., or 662° F., a little above the boiling point of quicksilver.

Quantity of air and pressure.—The blowing-machine belonging to the above blast-furnace is moved by a water wheel of 22 horse power; the pistons are 4 feet in diameter, have a 3½-feet stroke, work double, and expel 1200 cubic feet of air in the minute; or 600 cubic feet for each nozzle. The pressure of the air is equivalent to no more than 2 or 2¼ inches of mercury; formerly with cold air it amounted to 3½ inches. This furnace yields, upon an average, 5¼ tons of cast-iron daily, and consumes 1⅓ cwt. of coke for each cwt. of cast-iron produced; being 7 tons of coke *per diem.*

The consumption of the three flue fires is 30 pounds of small coal, for 100 pounds of cast-iron produced, which may be reckoned equivalent to 15 pounds of coke; hence altogether, each ton of cast-iron requires for its production 1½ tons of coke.

The same furnace worked with the cold blast, the same pressure, and the same ores, produced only 3½ tons of cast-iron daily, with an expenditure of 2·55 of coke for 1 of cast-iron; in which case the coke amounted to 9 tons daily.

The returns by the hot blast compared with those by the cold, are therefore as the numbers 3 and 2, which shows an advantage by the former plan of 50 per cent. The consumption of fuel in the two cases is as 8 to 9, being a saving in this article of about 11 per cent. Coke is used on account of sulphur in the coal.

Hot-blast heated by the flame of the furnace mouth.—This system is mounted in Staffordshire. The heating apparatus is there set immediately upon the mouth of the furnace; and is composed of two large cast-iron cylinders of the same length, the one within the other, leaving a space between them. This annular interval amounts to 16 inches and it is closed at top and bottom: but the innermost cylinder is open at both ends, and forms, indeed, the vent of the chimney or furnace. It carries nine rows of pipes, three in each row, which cross its interior, and open into the annular space.

The flame of the furnace passes between the intervals of the cross pipes, heating them, and also the two upright cylinders with which they are connected. The air of the blowing machine arrives by a vertical pipe, which is placed at the back of the furnace; it enters into the above annular space, and thence circulates, with more or less velocity, through the 27 cross tubes, upon which the flame is continually playing; lastly, it is drawn through to the bottom of the annular space; the two tubes which conduct it to the two tuyères, pass down within the brickwork of the furnace, and thus prevent the dissipation of its heat.

Below this heating apparatus there is a door for putting the charges into the furnace.

The above arrangement does not seem to be the best for obtaining the greatest possible heat for the blast, nor for favoring the free action of the furnace; but it illustrates perfectly well the principle of this application. A serpentine movement in a long bent hot channel would be much better adapted for communicating heat to so bad a conductor as air is known to be.

In the month of July, 1836, I paid a visit to Codner Park and Butterly works, in Derbyshire, belonging to the eminent iron-masters, Messrs. Jessop & Co., where I was kindly permitted not only to study the various processes of the manufacture of cast and wrought iron, but to inspect the registers of the products of cast iron in their blast furnaces for several years back. It appeared that in the year 1829, only 29 tons of cast-iron were made weekly in each of the blast furnaces at Codner Park. They were then worked with coke, and blown with cold air. Each ton of iron required for its production, at that time, 6·82 tons of coals, made into coke for smelting; with 2·64 of roasted iron ore (carbonate), called mine; and 0·87 of limestone, the *castine* of the French.

In 1835 and 1836, the same furnaces turned out weekly 49 tons of cast-iron each; and every ton of iron required for its production only 3 tons of coal (not made into coke); 2·72 tons of mine; and 0·77 of lime.

In 1829, and for many years before, as well as one or two after, each ton of coals is said to have cost for coking the sum of 6*s.*, whence the 6·82 tons of coals then converted into coke for smelting one ton of iron, cost fully 40*s.* in coking alone, in addition to their prime cost. The saving in this respect, therefore, is 40*s.* upon each ton of iron, besides the saving of fully half the coal, and the increased produce of nearly 60 per cent. of metal per week. The iron-master pays the patentee 1*s.* upon every ton of iron which he makes, and, at the prices of 1836, he lessened his expenses by at least 30*s.* or 40*s.* per ton by the patent improvement.

The following tabular view of the progression in the management and results of the hot blast, is given by M. Dufrènoy, after visiting the various iron works in this country where it had been introduced.

“At the Clyde iron works, near Glasgow; in 1829, when the combustion was effected by the cold air blast,—

	Coal.		
	Tons.	cwt.	lbs
There were consumed, for smelting, 3 tons of coke, equivalent to	6	13	0
— for the blowing engine	1	0	7
Total coal per ton of iron	7	13	7
Limestone	0	10½	0
In 1831, with the hot blast at 450° F., coke being still used in smelting,—			
There were consumed, for smelting, 1 ton, 18 cwt. of coke, equivalent to	4	6	0
— for heating the air, 5 cwt. — for the blowing engine, 7 cwt. 4 lbs.	0	12	4
Total coal per ton of iron	4	18	4
Limestone	0	9	0
In July, 1833, with the hot blast at 612° F., raw coal alone being used for smelting,—			
There were consumed: for smelting	2	0	0
— for heating the air	0	8	0
— for the blowing engine	0	11	2
Total coal per ton of iron	2	19	2
Limestone	0	7	0

"At the last period the use of hot air had increased the make of the furnaces by more than one third, and had consequently produced a great saving of expense in the article of labor. The quantity of blast necessary for the furnaces was also sensibly diminished for a blowing engine of seventy-horse power, which, in 1829, served only for three blast furnaces, was now sufficient for the supply of four.

"On comparing these several results, we find that the economy of fuel is in proportion to the temperature to which the air is raised. As for the actual saving, it varies in every work, according to the nature of the coal, and the care with which the operation is conducted.

"This process, though it has been four years in use in the works near Glasgow (which it has rescued from certain ruin), has scarcely passed the borders of Scotland; the marvellous advantages, however, which it has produced, are beginning to triumph over prejudice, and gradually to extend its use into the different English iron districts. There are one-and-twenty works, containing altogether sixty-seven blast furnaces, in which hot air is used. The pig iron run out of these furnaces is generally No. 1, and is fit for making the most delicate castings. This process is equally applicable to forge pigs for the manufacture of bar iron; since in order to obtain this quality of iron, it is only necessary to alter the proportion of fuel and mineral. In the forges of the Tyne iron-works, near Newcastle, and of Codner Park, near Derby, pigs made in furnaces blown by hot air, are alone used in the manufacture of bar iron!

"In the side of the tuyère pipe a small hole is made, by means of which the heat of the air may be ascertained at any moment. This precaution is indispensable, it being of importance to the beneficial use of hot air, that it be kept at a uniformly high temperature. With a proper apparatus the air is raised to 612 degrees Fahr., which is a greater heat, by several degrees, than is necessary for the fusion of lead."

"At Calder works the consumption of fuel has diminished in the proportion of 7 tons 17 cwts. to 2 tons 2 cwts. There has also been a great diminution of expense in limestone, of which only 5½ cwts. are now used, instead of 13 cwts., which were used in 1828. This decrease results, as I have already said, from the high temperature which the furnace has acquired since the introduction of hot air.

"The quantity of blast has been reduced from 3500 cubic feet per minute, to 2627 cubic feet; the pressure also has been reduced from 3¼ to 2¾ lbs."

Of the refinery of cast-iron, or its conversion into bar-iron, in England.—This operation is naturally divisible into three distinct parts. The first, or the finery properly speaking, is executed in peculiar furnaces called *running out fires;* the second operation completes the first, and is called *puddling;* and the third consists in welding several iron bars together, and working them under forge hammers, and between rolls.

1. The *finery furnaces* are composed of a body of brickwork, about 9 feet square; rising but little above the surface of the ground. The hearth, placed in the middle, is two feet and a half deep; it is rectangular, being in general, 3 feet by 2, with its greatest side parallel to the face of the tuyères; and it is made of cast iron in four plates. On the side of the tuyères there is a single brick wall. On the three other sides, sheet iron doors are placed, to prevent the external air from cooling the metal, which is almost always worked under an open shed, or in the open air, but never in a space surrounded by walls. The chimney, from 15 to 18 feet high, is supported upon four columns of cast iron; its lintel is four feet above the level of the hearth, in order that the laborers may work without restraint.

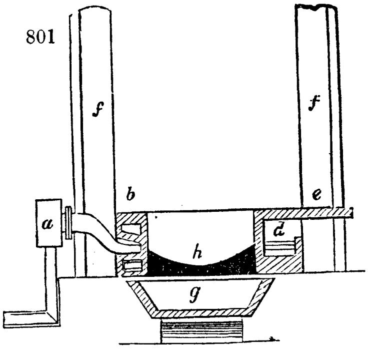
The number of tuyères is from two to three; they are placed at the height of the lip of the crucible or hearth, and distributed so as to divide its length into equal parts; their axes being inclined towards the bottom, at an angle of from 25° to 30°, so as to point upon the bath of melted metal as it flows. The cast-iron nose-pipe is incased, and water is made to circulate in the hollow space by means of cylindrical tubes; being introduced by one tube, and let off by another, so as to prevent the tuyères from getting burned in the process.

Two nozzles are usually placed in each tuyère, to render the blast constant and uniform; and for the same end, the air impelled by the bellows, is sometimes received at first in a regulator. The quantity of air blown into the fineries is considerable; being nearly 400 cubic feet per minute for each finery; or about the eighth part of the consumption of a blast furnace.

The finery furnace, or running out fire, is represented in *figs.* 801 and 802. It is a smelting hearth, in which by first fusing and then cooling gray cast iron in a peculiar way, it is converted into white cast iron, called fine iron, or fine metal, of the quality of forge pig, for making malleable iron by the puddling process. The furnace resembles the forge hearth employed in Germany and France for converting forge pig into wrought iron; but it differs, particularly in this, that the fused iron is run out into an oblong iron trough, for sudden congelation.

a is the air-chest, in communication with the blowing cylinder, or bellows; the air being conducted through at least two blast pipes to the fire, and sometimes through even 4 or 6 pipes. *b* is the side of the furnace, corresponding to the tuyère plates, in

801



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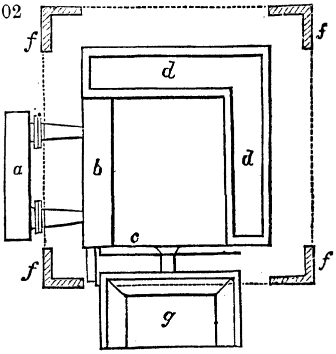


which are the openings for the blast pipes. All the sides of the furnace are hollow, and are kept cool by the circulation of water through the cavity between them. *c* is the front wall of the furnace, having a strong cast iron plate containing the tap holes for running off the melted metal. *d d* is the exterior wall of the furnace, which corresponds to the *contre-vent* and ash-hearth of the French refining forge. *e*, is the top plate upon which the coke is piled up in store. *f f*, *f f*, iron props of the chimney, (not shown in this view). *g*, cast iron trough into which the fine iron is run off in fusion; which is sometimes made in one piece, but more usually in separate plates joined together. Beneath this mould a stream of water is made to flow. *h* is the bottom of the hearth, covered with sand.

In the finery process, the hearth or crucible of the furnace is filled with coke; then six pigs of cast iron are laid horizontally on the hearth, namely, four of them parallel to the four sides, and two in the middle above; and the whole is covered up in a dome-form, with a heap of coke. The fire is now lighted, and in a quarter of an hour the blast is applied. The cast iron flows down gradually, and collects in the crucible; more coke being added as the first quantity burns away. This operation proceeds by itself; the melted metal is not stirred about, as in some modes of refinery, and the temperature is always kept high enough to preserve the metal liquid. During this stage the coals are observed continually heaving up, a movement due in part to the action of the blast, and in part to an expansion caused in the metal by the discharge of gaseous oxyde of carbon. When all the pig iron is collected at the bottom of the hearth, which happens commonly at the end of two hours, or two and a half, the tap hole is opened, and the *fine* metal flows out with the slag, into the loam-coated pit, on a plate 10 feet long, 3 broad, and from 2 inches to 2½ thick. A portion of the slag forms a small crust on the surface of the metal; but most part of it collects in a basin scooped out at the bottom of the pit, into which the fine metal is run.

A large quantity of water is thrown on the fine metal, with the view of rendering it brittle, and perhaps of partially oxydizing it. This metal suddenly cooled, is very white, and possesses in general a fibrous radiated texture; or sometimes a cellular, including a considerable number of small spherical cavities, like a decomposed amygdaloid rock. If the cast iron be of bad quality, a little limestone is occasionally used in the above operation.

Three samples of cinder, analyzed by Berthier, gave.

Silica 0·276; protox. of iron, 0·612; alumina, 0·040; phosp. acid, 0·072, Dudley.
— 0·368 — 0·610 — 0·015; puddling of Dowlais.
— 0·424 — 0·520 — 0·033; ditto.

The remarkable fact of the presence of phosphoric acid, shows how important this operation is to the purification of the iron. The charge varies from a ton and a quarter to a ton and a half of pigs; and the loss by the process varies from 12 to 17 per cent.

The *fine metal* is broken into fragments, and sent to the puddling furnace after the product of each operation has been weighed. The coal consumed in the fine metal process is from 4 to 5 hundred weight for the ton of cast iron. About 10 tons may be refined *per diem*, a quantity somewhat greater than the supply from a blast furnace; but the fineries are not worked on the Sundays; and therefore a smelting furnace just keeps one of them in play. Whatever care be taken in this process, the bar iron finally resulting is never so good as if wood charcoal had been used in the refinery; and hence in making sheet iron for the tin plate manufacture, wood charcoal is substituted for coke in one Welsh establishment. The cast iron treated with charcoal, gets into clots or lumps in the finery furnace, which are lifted out, set under the hammer, and flattened into thin cakes.

The main effect, of the finery process, is probably the separation of the plumbaginous part of the charcoal, which is disseminated through the gray cast iron in a state of imperfect chemical combination. When that is removed the metal becomes more homogeneous, having no crystalline carbon present to counteract its transition into pure iron; much of the silica and manganese are also vitrified together, and run off in the finery cinder.

2. The *puddling furnace* is of the reverberatory form. It is bound generally with iron, as represented in the side view, *fig.* 803, by means of horizontal and vertical bars, which are joined together and fixed by wedges, to prevent them from starting asunder. Very frequently, indeed, the reverberatory furnaces are armed with cast-iron plates over the whole surface. These are retained by upright bars of cast iron applied to the side wall and by horizontal bars of iron, placed across the arch or roof. The furnace itself is divided interiorly into three parts; the *fire-place*, the *hearth*, and the *flue*. The *fire-place* varies from 3½ to 4½ feet long, by from 2 feet 8 inches to 3 feet 4 inches wide. The door way by which the coke is charged, is 8 inches square, and is bevelled off towards the outside of the furnace. This opening consists entirely of cast iron, and has a quantity of coal gathered round it. The bars of the fire grate are moveable, to admit of more readily clearing them from ashes.

803

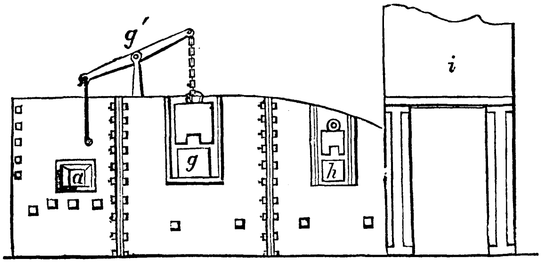
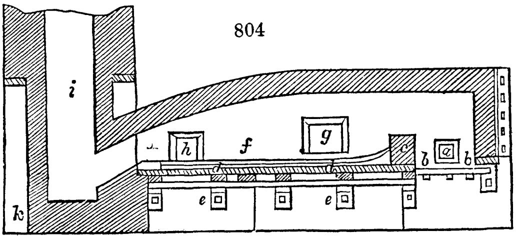


Fig. 804 is a longitudinal section referring to the elevation, *fig.* 803; and *fig.* 805, is a ground plan. When the furnace is a single one, a square hole is left in the side of the fire-place opposite to the door, through which the rakes are introduced, in order to be heated.

804



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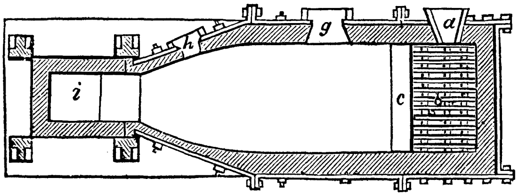
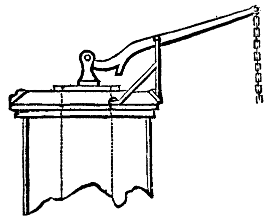


a is the fire door; *b*, the grate; *c*, the fire bridge; *d d*, cast-iron hearth plates, resting upon cast-iron beams *e e*, which are bolted upon both sides to the cast-iron binding plates of the furnace. *f* is the hearth covered with cinders or sand; *g*, is the main working door, which may be opened and shut by means of a lever *g′*, and chain to move it up and down. In this large door there is a hole 5 inches square, through which the iron may be worked with the paddles or rakes; it may also be closed air-tight. There is a second working door *h*, near the flue, for introducing the cast iron, so that it may soften slowly, till it be ready for drawing towards the bridge. *i*, is the chimney, from 30 to 50 feet high, which receives commonly the flues of two furnaces, each provided with a damper plate or *register*. *Fig*. 806, shows the main damper for the top of the common chimney, which may be opened or shut to any degree by means of the lever and chain. *k*, *fig*. 804, is the tap or floss hole for running off the slag or cinder.

806



The sole is sometimes made of bricks, sometimes of cast iron. In the first case it is composed of fire-bricks set on edge, forming a species of flat vault. It rests immediately on a body of brickwork either solid or arched below. When it is made of cast iron, which is now beginning to be the general practice, it may be made either of one piece or of several. It is commonly in a single piece, which, however, causes the inconvenience of reconstructing the furnace entirely when the sole is to be changed. In this case it is a little hollow, as is shown in the preceding vertical section; but if it consists of several pieces, it is usually made flat.

The hearths of cast iron rest upon cast iron pillars, to the number of four or five; which are supported on pedestals of cast iron placed on large blocks of stone. Such an arrangement is shown in the figure, where also the square hole *a*, *fig*. 803, for heating the rake irons, may be observed. The length of the hearth is usually six feet; and its breadth varies from one part to another. Its greatest breadth, which is opposite the door, is four feet. In the furnace, whose horizontal plan is given above, and which produces good results, the sole exhibits, in this part, a species of ear, which enters into the mouth of the door. At its origin towards the fireplace, it is 2 feet 10 inches wide; from the fire it is separated, moreover, by a low wall of bricks (the fire-bridge) 10 inches thick, and from 3 inches to 5 high. At the other extremity its breadth is 2 feet. The curvature presented by the sides of the sole or hearth is not symmetrical; for sometimes it makes an advancement, as is observable in the plan. At the extremity of the sole furthest from the fire, there is a low rising in the bricks of 2½ inches, called the altar, for preventing the metal from running out at the *floss-hole* when it begins to fuse. Beyond this shelf the sole terminates in an inclined plane, which leads to the *floss*, or outlet of the slag from the furnace. This *floss* is a little below the level of the sole, and is hollowed out of the basement of the chimney. The slag is prevented from concreting here, by the flame being made to pass over it, in its way to the sunk entry of the chimney; and there is also a plate of cast iron near this opening, on which a moderate fire is kept up to preserve the fluidity of the scoriæ, and to burn the gases that escape from the furnace, as also to quicken the draught, and to keep the remote end of the furnace warm. On the top of this iron plate, and at the bottom of the inclined plane, the cinder accumulates in a small cavity, whence it afterwards flows away; whenever it tends to congeal, the workman must clear it out with his rake.

The door is a cast iron frame filled up inside with fire-bricks; through a small hole in its bottom the workmen can observe the state of the furnace. This hole is at other times shut with a stopper. The chimney has an area of from 14 to 16 inches.

The hearth stands 3 feet above the ground. Its arched roof, only one brick thick, is raised 2 feet above the fire-bridge, and above the level of the sole, taken at the middle of the furnace. At its extreme point near the chimney, its elevation is only 8 inches; and the same height is given to the opening of the chimney.

In most iron works the sole is covered with a layer of refractory sand from 2½ to 3 inches thick, which is lightly beat down with a shovel. At each operation a portion of the sand is carried away; and is replaced before another. Within these few years, there has been substituted for the sand a body of pounded slags; a substitution which has occasioned, it is said, a great economy of iron and fuel.

The fine metal obtained by the coke is *puddled* by a continuous operation, which calls for much care and skill on the part of the workmen. To charge the puddling furnace, pieces of *fine metal* are successively introduced with a shovel, and laid one over another on the sides of the hearth, in the form of piles rising to the roof; the middle being left open for puddling the metal, as it is successively fused. Indeed, the whole are kept as far separate as possible, to give free circulation to the air round the piles. The working door of the furnace is now closed, fuel is laid on the grate, and the mouth of the fireplace, as well as the side opening of the grate, are both filled up with coal, at the same time that the damper is entirely opened.

The fine metal in about twenty minutes comes to a white-red heat, and its thin-edged fragments begin to melt and fall in drops on the sole of the furnace. At this period the workman opens the small hole of the furnace door, detaches with a rake the pieces of fine metal that begin to melt, tries to expose new surfaces to the action of the heat, and in order to prevent the metal from running together as it softens, he removes it from the vicinity of the fire-bridge. When the whole of the fine metal has thus got reduced to a pasty condition, he must lower the temperature of the furnace, to prevent it from becoming more fluid. He closes the damper, takes out a portion of the fire, and the ribs of the grate, and also throws a little water sometimes on the semi-fused mass. He then works about with his paddle the clotty metal, which swells up, with the discharge of gaseous oxyde of carbon, burning with a blue flame, as if the bath were on fire. The metal becomes finer by degrees, and less fusible; or in the language of the workmen, it begins to get *dry*. The disengagement of the oxyde of carbon diminishes, and soon stops. The workmen continue meanwhile to puddle the metal till the whole charge be reduced to the state of incoherent sand; and at that time, the ribs of the grate are replaced, the fire is restored, and the register is progressively opened up. With the return of the heat, the particles of metal begin to agglutinate, the charge becomes more difficult to raise, or in the laborers' language, it *works heavy*. The refining is now finished, and nothing remains but to gather the iron into balls. The founder with his paddle takes now a little lump of metal, as a nucleus, and makes it roll about on the surface of the furnace, so as to collect more metal, and form a ball of about 60 or 70 pounds weight. With a kind of rake, called in England a *dolly*, and which he heats beforehand, the workman sets this ball on that side of the furnace most exposed to the action of the heat, in order to unite its different particles; which he then squeezes together to force out the scoriæ. When all the balls are fashioned, (they take about 20 minutes work,) the small opening of the working door is closed with a brick, to cause the heat to rise, and to facilitate the welding. Each ball is then lifted out, either with tongs, if roughing rollers are to be used, as in Wales, or with an iron rod welded to the lump as a handle, if the hammer is to be employed, as in Staffordshire. Thus we see that the operation lasts in whole from 2 hours to 2½; in a quarter of an hour, the fine metal melts at its edges, when the puddling begins, in order to effect its division; at the end of an hour or an hour and a half, the metal is entirely reduced to a sand; a state that is kept up for half an hour by continual stirring; and finally, the balling operation takes nearly the same time.

The charge for each operation is from 3½ to 4 hundred weight; and sometimes the cuttings of bar-ends are introduced, which are puddled apart. The loss of iron is here very variable, according to the degree of skill in the workman, who by negligence may suffer a considerable body of iron to scorify or to flow into the hearth and raise the bottom. In good working, the loss is from 8 to 10 per cent. In Wales, the consumption of coal is estimated at one ton for every ton of fine metal. About five puddling furnaces are required for the service of one smelting furnace and one finery. The hearth of the puddling furnace should be exposed to heat for 12 hours before the work begins on the Mondays; and on the Saturdays, the old sole must be cleared out, by melting it off, and running it out by the floss-hole.

Mr. Schafthault obtained, in May, 1835, a patent for the conversion of cast into wrought iron, by adding a mixture of black oxyde of manganese, common salt, and potter's clay, in certain small portions, successively, to the melting iron in the puddling furnace.

The reheating furnaces, balling furnaces, or mill furnaces, are analogous to the puddling furnaces, but only of larger dimensions.

The wood charcoal forge hearth is employed for working up scrap iron into boiler plate, &c. Here 22 bushels of charcoal are consumed in making one ton of iron of that description, from boiler plate parings.

Machines for forging and condensing the iron.—In England there are employed for the forging and drawing out of the iron, cast-iron hammers of great weight, and cylinders of different dimensions, for beating out the balls, or extending the iron into bars, as also powerful shears. These several mechanisms are moved either by a steam engine, as in Staffordshire, and in almost all the other counties of England, or by water-wheels when the localities are favorable, as in many establishments in South Wales. We shall here offer some details concerning these machines.

The main driving shaft usually carries at either end a large toothed wheel, which communicates motion to the different machines through smaller toothed wheels. Of these, there are commonly six, four of which drive four different systems of cylinders, and the two others work the hammer and the shears. The different cylinders of an iron work should never be placed on the same arbor, because they are not to move together, and they must have different velocities, according to their diameter. In order to economize time and facilitate labor, care is taken to associate on one side of the motive machine the hammer, the shears, and the reducing cylinders; and on the other side to place the several systems of cylinders for drawing out the iron into bars. For the same reason the puddling furnaces ought to be grouped on the side of the hammer; and the reheating furnaces on the other side of the works.

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The hammers, *fig.* 807, are made entirely of cast iron; they are nearly 10 feet long and consist usually of two parts, the helve *c*, and the head or pane *d*. The latter enters

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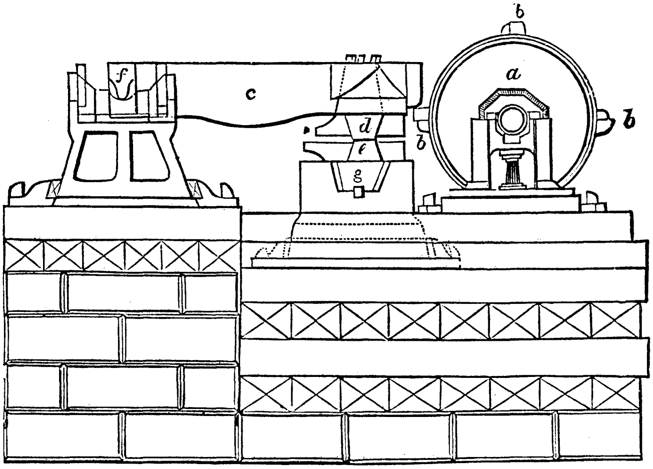


with friction into the former, and is retained in its place by wedges of iron or wood The head consists of several faces or planes receding from each other; for the purpose of giving different forms to the ball lumps. A ring of cast-iron *a*, called the *cam-ring bag*, bearing moveable cams *b b*, drives the hammer *d*, by lifting it up round its fulcrum *f*, and then letting it fall alternately. In one iron work, this ring was found to be 3 feet in diameter, 18 inches thick, and to weigh 4 tons. The weight of the helve (handle) of the corresponding hammer was 3 tons and a half, and that of the head of the hammer, 8 hundred weight.

The anvil *e* consists also of two parts; the one called the pane of the anvil, is the counterpart of the pane of the hammer; it likewise weighs 8 hundred weight. The second, *g*, named the stock of the anvil, weighs 4 tons. Its form is a parallelopiped, with the edges rounded. The *bloom* or rough ball, from the puddle furnace, is laid and turned about upon it, by means of a rod of iron welded to each of them, called a *porter*. Since the weight of these pieces is very great, and the shocks very considerable, the utmost precautions should be taken in setting the hammer and its anvil upon a substantial mass of masonry, as shown in the figure, over which is laid a double, or even quadruple flooring of wood, formed of beams placed in transverse layers close to each other. Such beams possess an elastic force, and thereby partially destroy the injurous reaction of the shock. In some works, a six-feet cube of cast iron is placed as a pedestal to the anvil.

Forge hammers are very frequently mounted as levers of the first kind, with the centre of motion about one third or one fourth of the length of the helve from the cam wheel. The principle of this construction will be understood by inspection of *fig.* 816. The short end of the lever which is struck down by the tappet *c*, is driven against the end of an elastic beam *a*, and immediately rebounds, causing the long end to strike a harder blow upon the anvil *s*.

The shears are composed of two branches, the one fixed and the other moveable, each formed of two pieces. The fixed branch is a cast-iron plate, which forms one mass with a horizontal base fixed to a piece of wood or cast iron buried in the ground. A sharpened chisel is fastened to its upper part by screws and nuts. The moveable branch is likewise of cast iron; it bears an axis round which it turns, and this axis passes through the fixed part. It is also furnished with a cutting chisel, fixed on by nuts and screws. An eccentric or an ellipse, moved directly by a toothed wheel, lifts the moveable branch of the shears, and forces it to cut the iron bars presented to it. The pressure exerted by these scissors is such, that they can cut without difficulty, iron bars, one half or two thirds of an inch thick.

Cylinders.—The compression between cylinders now effects, in a few seconds, that condensation and distribution of the fibres, which, 40 years ago, could not be accomplished till after many heats in the furnace, and many blows of the hammer. The cylinders may be distinguished into two kinds; 1. those which serve to draw out the ball, called *puddling rolls*, or roughing rolls, and which are, in fact, reducing cylinders; 2. the cylinders of extension, called *rollers*, for drawing into bars the massive iron after it has received a welding, to make it more malleable. This second kind of cylinders is subdivided into several varieties, according to the patterns of bar iron that are required. These may vary from 2 inches square to less than one sixth of an inch.

Beneath the cylinders there is usually formed an oblong fosse, into which the scoriæ and the scales fall when the iron is compressed. The sides of this fosse, constructed of stone, are founded on a body of solid masonry, capable of supporting the enormous load of the cylinders. Beams of wood form in some measure the sides of this pit, to which cylinders may be made fast, by securing them with screws and bolts. Massive bars of cast iron are found, however, to answer still better, not only because the uprights and bearers may be more solidly fixed to them, but because the basement of heavy metal is more difficult to shatter or displace, an accident which happens frequently to the wooden beams. A rill of water is supplied by a pipe to each pair of cylinders, to hinder them from getting hot; as also to prevent the hot iron from adhering to the cylinder, by cooling its surface, and perhaps producing on it a slight degree of oxydizement.

The shafts are one foot in diameter for the hammer and the roughing rolls; and six inches where they communicate motion to the cylinders destined to draw the iron into bars.

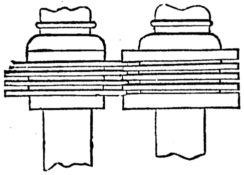
The *roughing rolls* are employed either to work out the lump or ball immediately after it leaves the puddling furnace, as in the Welsh forges, or only to draw out the piece, after it has been shaped under the hammer, as is practised in most of the Staffordshire establishments. These roughing cylinders are generally 7 feet long, including the trunnions, or 5 feet between the bearers, and 18 inches diameter; and weigh in the whole from 4 to 4½ tons. They contain from 5 to 7 grooves, commonly of an elliptical form, one smaller than another in regular progression, as is seen in *fig.* 808. The small axis of each ellipse, as formed by the union of the upper and under grooves, is always placed in the vertical direction, and is equal to the great axis, or horizontal axis of the succeeding groove; so that in transferring the bar from one groove to another, it must receive a quarter of a revolution, whereby the iron gets elongated in every direction. Sometimes the roughing rolls serve as preparatory cylinders, in which case they bear towards one extremity rectangular grooves, as the figure exhibits. Several of these large grooves are bestudded with small asperities analogous to the teeth of files, for biting the lump of iron, and preventing its sliding. On a level with the under side of the grooves of the lower cylinder, there is a plate of cast iron with notches in its edge adapted to the grooves. This piece, called the apron, rests on iron rods, and serves to support the balls and bars exposed to the action of the rollers, and to receive the fragments of ill-welded metal, which fall off during the drawing. The *housing frames* in which the rollers are supported and revolve, are made of great strength. Their height is 5 feet; their thickness is 1 foot in the side perpendicular to the axis of the cylinders, and 10 inches in the other. Each pair of bearers is connected at their upper ends by two iron rods, on which the workmen rest their tongs or pincers for passing the lump or bar from one side of the cylinders to the other.

The cods or bushes are each composed of two pieces; the one of hard brass, which presents a cylindrical notch, is framed into the other which is made of cast iron, as is clearly seen in *fig.* 808.

The iron bar delivered from the square grooves, is cut by the shears into short lengths, which are collected in a bundle in order to be welded together. When this bundle of bars has become hot enough in the furnace, it is conveyed to the rollers; which differ in their arrangement according as they are meant to draw iron from a large or small piece. The first, *fig.* 808, possess both elliptical and rectangular grooves; are 1 foot in diameter and 3 feet long between the bearers. The bar is not finished under these cylinders, but is transferred to another pair, whose grooves have the dimensions proper for the bar, with a round, triangular, rectangular, or fillet form. The triangular grooves made use of for square iron, have for their profile an isosceles triangle, slightly obtuse, so that the space left by the two grooves together may be a rhombus, differing little from a square, and whose smaller diagonal is vertical. When the bar is to be passed successively through several grooves of this kind, the larger or horizontal diagonal of each following groove is made equal to the smaller or upright of the preceding one, whereby the iron must be turned one fourth round at each successive draught, and thus receive pressure in opposite directions. Indeed, the bar is often turned in succession through the triangular and rectangular grooves, that its fibres may be more accurately worked together. The decrement in the capacity of the grooves follows the proportion of 15 to 11.

When it is intended to reduce the iron to a small rod, the cylinders have such a diameter, that three may be set in the same housing frame. The lower and middle cylinders are employed as roughing rollers, while the upper and middle ones are made to draw out the rod. When a rod or bar is to be drawn with a channel or gutter in its face, the rooves of the rollers are suitably formed.

To draw out square rods of a very small size, as nail-rods, a system of small rollers is employed, called *slitters*. Their ridges are sharp-edged, and enter into the opposite grooves 2½ inches deep; so that the flat bar in passing between such rollers is instantaneously divided into several slips. For this purpose the rollers represented in *fig*. 809 may be put on and removed from the shaft at pleasure.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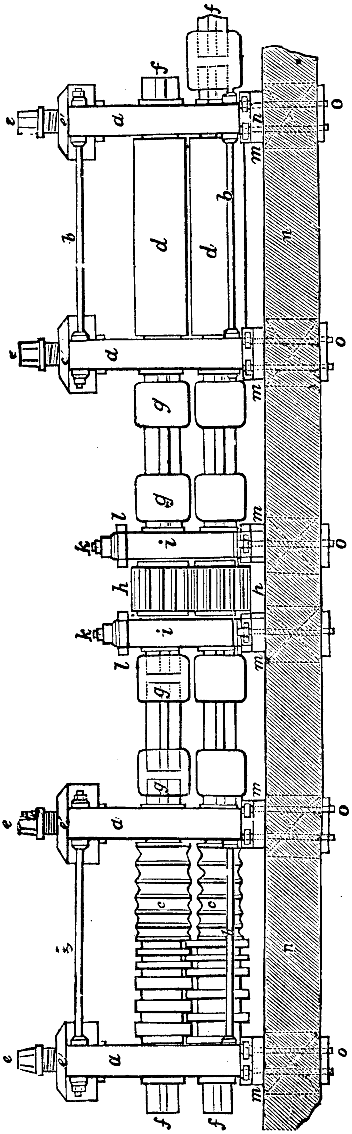

The velocity of the cylinders varies with their dimensions. In one work, cylinders for drawing out iron of from one third to two thirds of an inch thick, make 140 revolutions per minute; while those for iron of from two thirds of an inch to 3 inches, make only 65. In another work, the cylinders for two inch iron, make 95 revolutions per minute; those for iron from two thirds of an inch to an inch and a third, make 128; and those for bars from one third to two thirds of an inch, 150. The *roughing rollers* move with only one third the velocity of the drawing cylinders.

The shingling and plate-rolling mill is represented in *fig*. 808. The shingling mill, for converting the blooms from the balling furnace into bars, consists of two sets of grooved cylinders, the first being called *puddling rolls* or *roughing rolls;* the second are for reducing or drawing the iron into mill-bars, and are called simply *rolls*.

a, a, a, a, are the powerful uprights or standards called *housing frames*, of cast iron, in which the gudgeons of the rolls are set to revolve; *b, b, b, b*, are bolt rods for binding these frames together at top and bottom; *c*, are the roughing rolls, having each a series of triangular grooves, such that between those of the upper and under cylinder, rectangular concavities are formed in the circumference with slightly sloping sides. The end groove to the right of *c*, should be channelled like a rough file, in order to take the better hold of the blooms, or to bite the metal, as the workmen say; and give it the preparatory elongation for entering into and passing through the remaining grooves till it comes to the square ones, where it becomes a mill-bar. *d, d*, are the smooth cylinders, hardened upon the surface, or *chilled* as it is called, by being cast in iron moulds, for rolling iron into plates or hoops. *e, e, e, e*, are strong screws with rectangular threads, which work by means of a wrench or key, into the nuts *e' e' e' e'*, fixed in the standards; they serve to regulate the height of the plummer blocks or bearers of the gudgeons, and thereby the distance between the upper and under cylinders. *f* is a junction shaft; *g g, g*, are solid coupling boxes, which embrace the two separate ends of the shafts, and make them turn together. *h, h*, are junction pinions, whereby motion is communicated from the driving shaft *f*, through the under pinion to the upper one, and thus to both upper and under rolls at once. *i, i*, are the pinion standards in which their shafts run; they are smaller than the uprights of the rolls. *k, k*, are screws for fastening the head pieces *l* to the top of the pinion standards. All the standards are provided with sole plates *m*, whereby they are screwed to the foundation beams *n*, of wood or preferably iron, as shown by dotted lines; *o o* are the binding screw bolts. Each pair of rolls at work is kept cool by a small stream of water let down upon it from a pipe and stop-cock.

In the cylinder drawing, the workman who holds the ball in tongs, passes it into the first of the elliptical grooves; and a second workman on the other side of the cylinders, receives this lump, and hands it over to the first, who re-passes it between the rollers, after bringing them somewhat closer to each other, by giving a turn to the adjusting pressure screws. After the lump has passed five or six times through the same groove, it has got an elliptical form, and is called in England a *bloom*. It is next passed through a second groove of less size, which stretches the iron bar. In this state it is subjected to a second pair of cylinders, by which the iron is drawn into flat bars, 4 inches broad and half an inch thick. Fragments of the ball or bloom fall round about the cylinders; which are afterwards added to the puddling charge. In a minute and a half, the rude lump is transformed into bars, with a neatness and rapidity which the inexperienced eye can hardly follow. A steam engine of thirty-horse power can *rough down* in a week, 200 tons of coarse iron.

This iron, called mill-bar iron, is however of too inferior a quality to be employed in any machinery; and it is subjected to another operation, which consists in welding several pieces together, and working them into a mass of the desired quality. The iron bars, while still hot, are cut by the shears into a length proportional to the size of iron bar that is wanted; and four rows of these are usually laid over each other into a heap or pile, which is placed in the *re-heating* furnace above described, and exposed to a free circulation of heat; one pile being set crosswise over another. In a half or three quarters of an hour, the iron is hot enough, and the pieces now sticking together, are carried in successive piles to the bar-drawing cylinders, to be converted into strong bars, which are reckoned of middle quality. When a very tough iron is wanted, as for anchors, another welding and rolling must be given. In the re-heating ovens, the loss is from 8 to 10 per cent. on the large bar iron, and from 10 to 12 in smaller work. A ton of iron consumes in this process about 150 lbs. of coals.

It is thought by many that a purer iron is obtained by subjecting the balls as they come out of the puddling furnace, to the action of the hammer at first, than to the roughing rollers; and that by the latter process vitrified specks remain in the metal, which the hammer expels. Hence, in some works, the balls are first worked under the forge-hammer; and these *stampings* being afterwards heated in the form of pies or cakes piled over each other, are passed through the roughing rollers.

Having given ample details concerning the manufacturing processes used in England for making cast iron, it may be proper to subjoin a few observations upon its chemical constitution. It has been generally believed and taught that the dark gray cast iron, No. 1 or No. 2, contains more carbon than the white cast iron; and that the superior quality of the former in tenacity and softness, is to be ascribed to that excess. But the distinguished German metallurgist, M. Karsten, in his instructive volume, "Handbuch der Eisenhüttenkunde," or manual of the art of smelting iron ores, has proved, on the contrary, that the white cast iron contains most charcoal; that this substance exists in it in a state of combination with the whole body of the iron; that the foliated or lamellar white cast iron contains as much carbon as iron can absorb in the liquid state; and that this constitutes a compound of 4 atoms of iron combined with 1 of charcoal, or 112+6; or $5\frac{1}{3}$ per cent.; whereas the dark gray cast iron contains generally from 3 to 4 per cent., in the state of plumbago merely dispersed through the metal. He has further confirmed his opinion, by causing the white variety to pass into the gray, and reciprocally. Thus, dark gray cast metal melted and suddenly cooled, gives a silvery white metal, hard and brittle. On the other hand, when the white cast iron is cooled very slowly after fusion, the condition of the carbon in it changes, and a dark gray cast iron is obtained. These phenomena show that the graphite or plumbago, which requires a high temperature for its formation, cannot be produced but by a slow cooling, which allows the carbon to agglomerate itself in the iron in the state of graphite; while under a rapid congelation, the carbon remains dissolved in the mass, and produces a white metal. Hence we may understand how each successive fusion of dark gray iron hardens and whitens it, though in contact with coke, by completing that chemical dissolution of the carbon on which the white state depends.

In the manufacture of the blackest No. 1 cast iron, it sometimes happens that a considerable quantity of a glistening carburet of iron appears, floating on the top of the metal as it is run out into the sand-moulds. This substance is called *kish* by the English workmen; and it affords a sure test of the good state of the furnace and quality of the iron.

The most remarkable fact relative to the smelting of cast iron, is the difference of product between the workings of the summer and the winter season, though all the materials and machinery be the same. In fact, no cold-blast furnace will carry so great a burden in summer as in winter, that is, afford so great a product of metal, or bear so great a charge of ore with the same quantity of coke. This difference is undoubtedly due to the dilated and humid state of the atmosphere in the warm season. A very competent judge of this matter, states the diminution in summer at from one fifth to one seventh, independently of deterioration of quality.

Some of the foreign irons, particularly certain Swedish and Russian bars, are imported into Great Britain in large quantities, and at prices much greater than those of the English bars, and therefore the modes of manufacturing such excellent metal deserve examination. All the best English cast steel, indeed, is made from the hoop L iron from Dannemora, in Sweden.

The processes pursued in the smelting works of the Continent have frequently in view to obtain from the ore malleable iron directly, in a pure or nearly pure state. The furnaces used for this purpose are of two kinds, called in French, 1. *Feux de Loupes*, or *Forges Catalanes;* and 2. *Fourneaux à pièce*, or *Forges Allemandes.*

In the Catalan, or French method, the ore previously roasted in a kiln is afterwards strongly torrefied in the forge before the smelting begins; operations which follow in immediate succession. Ores treated in this way should be very fusible and very rich; such as black oxyde of iron, hematites, and certain spathose iron ores. From 100 parts of ore, 50 of metallic iron have been procured, but the average product is 35. The furnaces employed are rectangular hearths, *figs.* 810, and 811, the water-blowing machine being employed to give the blast. See METALLURGY. There are three varieties of this forge; the Catalan, the Navarrese, and the Biscayan. The dimensions of the first, the one most generally employed, are as follows: 21 inches long, in the direction *p f*, *fig.* 811; 18½ broad, at the bottom of the hearth or *creuset*, in the line A B; and 17 inches deep, *fig.* 810. The tuyère, *q p*, is placed 9½ inches above the bottom, so that its axis is directed towards the opposite side, about 2 inches above the bottom. But it must be moveable, as its inclination needs to be changed, according to the stage of the operation, or the quantity of the ores. It is often raised or lowered with pellets of clay; and even with a graduated circle, for the workmen make a great mystery of this matter. The hearth is lined with a layer of *brasque* (loam and charcoal dust worked together), and the ore after being roasted is sifted; the small powder being set aside to be used in the course of the operation. The ore is piled up on the side opposite to the blast in a sharp saddle ridge, and it occupies one third of the furnace. In the remaining space of two thirds, the charcoal is put. To solidify the small ore on the hearth, it is covered with moist cinders mixed with clay.

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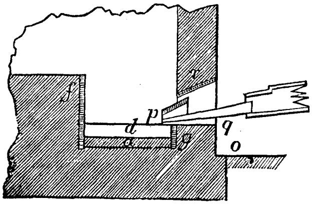

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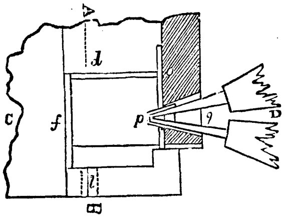

The fire is urged with moderation during the first two hours, the workman being continually employed in pressing down more charcoal as the former supply burns away, so as to keep the space full, and prevent the ore from crumbling down. By a blast so tempered at the beginning, the ore gets well calcined, and partially reduced in the way of cementation. But after two hours, the full force of the air is given; at which period the fusion ought to commence. It is easy to see whether the torrefaction be sufficiently advanced, by the aspect of the flame, as well as of the ore, which becomes spongy or cavernous; and the workman now completes the fusion, by detaching the pieces of ore from the bottom, and placing them in front of the tuyère. When the fine siftings are afterwards thrown upon the top, they must be watered, to prevent their being blown away, and to keep them evenly spread over the whole surface of the light fuel. They increase the quantity of the products, and give a proper fusibility to the scoriæ. When the scoriæ are viscid, the quantity of siftings must be diminished; but if thin, they must be increased. The excess of slag is allowed to run off by the *chio* or floss hole. The process lasts from five to six hours, after which the pasty mass is taken out, and placed under a hammer to be cut into lumps, which are afterwards forged into bars.

Each mass presents a mixed variety of iron and steel; in proportions which may be modified at pleasure; for by using much of the siftings, and making the tuyère dip towards the sole of the hearth, iron is the chief product; but if the operation be cor ducted slowly, with a small quantity of siftings, and an upraised tuyère, the quantity of steel is more considerable. This primitive process is favorably spoken of by M. Brongniart. The weight of the lump of metal varies from 200 to 400 pounds. As the consumption of charcoal is very great, amounting in the Palatinate or Rheinkreis to seven times the weight of iron obtained, though in the Pyrenees it is only thrice, the Catalan forge can be profitably employed only where wood is exceedingly cheap and abundant.

The *Fourneaux à pièce* of the French, or *Stuck-ofen* of the Germans, resembles *fig.* 385 (Copper); the tuyère (not shown there) having a dip towards the bottom of the hearth, where the smelted matter collects. When the operation is finished, that is, at least once in every 24 hours, one of the sides of the hearth must be demolished, to take out the pasty mass of iron, more or less pure. This furnace holds a middle place in the treatment of iron, between the Catalan forge and the cast-iron *floss-ofen*, or high-blast furnaces. The *stuck-ofen* are from 10 to 15 feet high, and about 3 feet in diameter at the hearth. Most usually there is only one aperture for the tuyère and for working; with a small one for the escape of the slag; on which account, the bellows are removed to make way for the lifting out of the lump of metal, which is done through an opening left on a level with the sole, temporarily closed with bricks and potters' clay, while the furnace is in action.

This outlet being closed, and the furnace filled with charcoal, fire is kindled at the bottom. Whenever the whole is in combustion, the roasted ore is introduced at the top in alternate charges with charcoal, till the proper quantity has been introduced. The ore falls down; and whenever it comes opposite to the tuyère the slag begins to flow, and the iron drops down and collects at the bottom of the hearth into the mass or *stuck;* and in proportion as this mass increases, the *floss-hole* for the slag and the tuyère is raised higher. When the quantity of iron accumulated in the hearth is judged to be sufficient, the bellows are stopped, the scoriæ are raked off, the little brick wall is taken down, and the mass of iron is removed by rakes and tongs. This mass is then flattened under the hammer, into a cake from 3 to 4 inches thick, and is cut into two lumps, which are submitted to a new operation; where it is treated in a peculiar refinery, lined with charcoal *brasque,* and exposed to a nearly horizontal blast. The above mass, seized in the jaws of a powerful tongs, is heated before the tuyère; a portion of the metal flows down to the bottom of the hearth, loses its carbon in a bath of rich slags or fused oxydes, and forms thereby a mass of iron thoroughly refined. The portion that remains in the tongs furnishes steel, which is drawn out into bars.

This process is employed in Carniola for smelting a granular oxyde of iron. The mass or *stuck* amounts to from 15 to 20 hundred weight, after each operation of 24 hours. Eight strong men are required to lift it out, and to carry it under a large hammer, where it is cut into pieces of about 1 cwt. each. These are afterwards refined and drawn into bars as above described. These furnaces are now almost generally abandoned on the Continent, in favor of *charcoal high* or *blast furnaces.*

Fig. 385 represents a *shachtofen* (but without the tuyère, which may be supposed to be in the usual place), and is, like all the continental *Hauts Fourneaux,* remarkable for the excessive thickness of its masonry. The charge is put in at the throat, near the summit of the octagonal or square concavity, for they are made of both forms. At the bottom of the hearth there is a dam-stone with its plate, for permitting the overflow of the slag, while it confines the subjacent fluid metal; as well as a tymp-stone with its plate, which forms the key to the front of the hearth; the boshes are a wide funnel, almost flat, to obstruct the easy descent of the charges, whereby the smelting with charcoal would proceed too rapidly. The bottom of the hearth is constructed of two large stones, and the hinder part of one great stone, called in German, *rückstein* (black stone), which the French have corrupted into *rustine.* In other countries of the Continent, the boshes are frequently a good deal more tapered downwards, and the hearth is larger than here represented. The refractory nature of the Hartz iron ores is the reason assigned for this peculiarity.

In Sweden there are blast-furnaces, *schachtofen,* 35 feet in height, measured from the boshes above the line of the hearth, or *creuset.* Their cavity has the form of an elongated ellipse, whose small diameter is 8 feet across, at a height of 14 feet above the bottom of the hearth; hence, at this part, the interior space constitutes a belly, corresponding with the upper part of the boshes. In other respects, the details of the construction of the Swedish furnaces resemble the one figured above. Marcher relates that a furnace of that kind, whose height was only 30 feet, in which brown hydrate of iron (*hematite*) was smelted, yielded 47 *per cent.* in cast-iron, at the rate of 5 hundred weight a day, or 36 hundred weight one week after another; and that in the production of 100 pounds of cast-iron, 130 pounds of charcoal were consumed. That furnace was worked with forge bellows, mounted with leather.

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The decarburation of cast-iron is merely a restoration of the carbon to the surface, in tracing inversely the same progressive steps as had carried it into the interior during the smelting of the ore. The oxygen of the air, acting first at the surface of the cast metal, upon the carbon which it finds there, burns it: fresh charcoal, oozing from the interior comes then to occupy the place of what had been dissipated; till, finally, the whole carbon is transferred from the centre to the surface, and is there converted into either carbonic acid gas, or oxyde of carbon; for no direct experiment has hitherto proved which of these is the precise product of this combustion.

This diffusibility of carbon through the whole mass of iron constitutes a movement by means of which cast-iron may be refined even without undergoing fusion, as is proved by a multitude of phenomena. Every workman has observed that steel loses a portion of its steely properties every time it is heated in contact with air.

On the above principle, cast-iron may be refined at one operation. Three kinds of iron are susceptible of this continuous process:—1. The speckled cast-iron, which contains such a proportion of oxygen and carbon as with the oxygen of the air and the carbon of the fuel may produce sufficient and complete saturation, but nothing in excess 2. The dark gray cast-iron. 3. The white cast-iron. The nature of the crude metal requires variations both in the forms of the furnaces, and in the manipulations.

Indeed, malleable iron may be obtained directly from the ores by one fusion. This mode of working is practised in the Pyrenees to a considerable extent. All the ores of iron are not adapted for this operation. Those in which the metallic oxyde is mixed with much earthy matter, do not answer well; but those composed of the pure black oxyde, red oxyde, and carbonate, succeed much better. To extract the metal from such ores, it is sufficient to expose them to a high temperature, in contact either with charcoal, or with carbonaceous gases; the metallic oxyde is speedily reduced. But when several earths are present, these tend continually, during the vitrification which they suffer, to retain in their vitreous mass the unreduced oxyde of iron. Were such earthy ores, as our ironstones, to be put into the low furnaces called *Catalan*, through which the charges pass with great rapidity, and in which the contact with the fuel is merely momentary, there would be found in the crucible or hearth merely a rich metallic glass, instead of a lump of metal.

In smelting and refining by a continuous operation, three different stages may be distinguished: 1. The roasting of the ore to expel the sulphur, which would be less easily separated afterwards. The roasting dissipates likewise the water, the carbonic acid, and any other volatile substances which the minerals may contain. 2. The deoxydizement and reduction to metal by exposure to charcoal or carbureted vapors. 3. The melting, agglutination, and refining of the metal to fit it for the heavy hammers where it gets nerve. There are several forges in which these three operations seem to be confounded into a single one, because, although still successive, they are practised at one single heating without interruption. In other forges, the processes are performed separately, or an interval elapses between each stage of the work. Three systems of this kind are known to exist:—1. The Corsican method; 2. The Catalan with wood charcoal; and 3. The Catalan with coke.

The furnaces of Corsica are a kind of semicircular basins, 18 inches in diameter, and 6 inches deep. These are excavated in an area, or a small elevation of masonry, 8 or 10 feet long by 5 or 6 broad, and covered in with a chimney. This area is quite similar to that of the ordinary hearths of our blast-furnaces.

The tuyère stands 5 or 6 inches above the basin, and has a slight inclination downwards. In Corsica, and the whole portion of Italy adjoining the Mediterranean shores, the iron ore is an oxyde similar to the specular ore of the Isle of Elba. This ore contains a little water, some carbonic acid, occasionally pyrites, but in small quantity. Before deoxydizing the ore, it is requisite to expel the water and carbonic acid combined with the oxyde, as well as the sulphur of the pyrites.

The operations of roasting, reduction, fusion, and agglutination, are executed in the same furnace. These are indeed divided into two stages, but the one is a continuation of the other. In the first, the two primary operations are performed at once;—the reduction of a portion of the roasted ore is begun at the same time that a portion of the raw ore is roasted: these two substances are afterwards separated. In the second stage, the deoxydizement of the metal is continued, which had begun in the preceding stage; it is then melted and agglutinated, so as to form a ball to be submitted to the forge-hammer.

The roasted pieces are broken down to the size of nuts, to make the reduction of the metal easier. In executing the first step, the basin and area of the furnace must be lined with a *brasque* of charcoal dust, 3, 4, or even 5 inches thick: over this *brasque* a mound is raised with lumps of charcoal, very hard, and 4 or 5 inches high. A semicircle is formed round the tuyère, the inner radius of which is 5 or 6 inches. This mass of charcoal is next surrounded with another pile of the roasted and broken ores, which must be covered with charcoal dust. The whole is sustained with large blocks of the raw ore, which form externally a third wall.

These three piles of charcoal, with roasted and unroasted ore, are raised in three successive beds, each 7 inches thick: they are separated from each other by a layer of charcoal dust of about an inch, which makes the whole 24 inches high. This is afterwards covered over with a thick coat of pounded charcoal.

The blocks of raw ore which compose the outward wall form a slope; the larger and stronger pieces are at the bottom, and the smaller in the upper part. The large blocks are sunk very firmly into the charcoal dust, to enable them better to resist the pressure from within.

On the bottom of the semicircular well formed within the charcoal lumps, kindled pieces are thrown, and over these, pieces of black charcoal; after which the blast of a water-blowing machine (*trompe*) is given. The fire is kept up by constantly throwing charcoal into the central well. At the beginning of the operation it is thrust down with wooden rods, lest it should affect the building; but when the heat becomes too intense for the workmen to come so near the hearth, a long iron rake is employed for the purpose. At the end of about 3 hours, the two processes of roasting and reduction are commonly finished: then the raw ore no longer exhales any fumes, and the roasted ore, being softened, unites into lumps more or less coherent.

The workman now removes the blocks of roasted ore which form the outer casing, rolls them to the spot where they are to be broken into small pieces, and pulls down the *brasque* (small charcoal) which surrounds the mass of reduced ore.

The second operation is executed by cleaning the basin, removing the slags, covering the basin anew with 2 or 3 brasques (coats of pounded charcoal), and piling up to the right and the left, two heaps of charcoal dust. Into the interval between these conical piles two or three baskets of charcoal are cast, and on its top some cakes of the reduced crude metal being laid, the blast is resumed. The cakes, as they heat, undergo a sort of liquation, or sweating, by the action of the earthy glasses on the unreduced black oxyde present. Very fusible slags flow down through the mass; and the iron, reduced and melted, passes finally through the coals, and falls into the slag basin below. To the first parcel of cakes, others are added in succession. In proportion as the slags proceeding from these run down, and the melted iron falls to the bottom, the thin slag is run off by an upper overflow or *chio* hole, and the reduced iron kept by the heat in the pasty condition, remains in the basin: all its parts get agglutinated, forming a soft mass, which is removed by means of a hooked pole in order to be forged. Each lump or *bloom* of malleable iron requires 3 hours and a half for its production.

The iron obtained by this process is in general soft, very malleable, and but little steely. In Corsica four workmen are employed at one forge. The produce of their labor is only about 4 cwts. of iron from 10 cwts. of ore and 20 of charcoal, mingled with wood of beech and chestnut. Though their ore contains on an average 65 per cent. of iron, only about 40 parts are extracted; evincing a prodigious waste, which remains in the slags.

The difference between the Corsican and the Catalonian methods consists in the latter roasting the ore at a distinct operation, and employing a second one in the reduction, agglutination, and refining of the metal. In the Catalonian forges, 100 pounds of iron are obtained from 300 pounds of ore and 310 pounds of charcoal; being a produce of only 33 per cent. It may be concluded that there is a notable loss, since the sparry iron ores, which are those principally smelted, contain on an average from 54 to 56 per cent. of iron. The same ores, smelted in the ordinary blast furnace, produce about 45 per cent. of cast iron.

On the Continent, iron is frequently refined from the cast metal of the blast furnaces by three operations, in three different ways. In one, the pig being melted, with aspersion of water, a cake is obtained, which is again melted in order to form a second cake. This being treated in the refinery fire, is then worked into a *bloom*. In another system, the pig iron is melted and cast into plates: these are melted anew in order to obtain crude balls, which are finally worked into blooms. In a third mode of manufacture, the pig-iron is melted and cast into plates, which are roasted, and then strongly heated, to form a bloom.

The French fusible ores, such as the silicates of iron, are very apt to smelt into white cast iron. An excess of fluxes, light charcoals, too strong a blast, produce the same results. A surcharge of ores which deranges the furnace and affords impure slags mixed with much iron, too rapid a slope in the boshes, too low a degree of heat, and too great condensation of the materials in the upper part of the furnace; all tend also to produce a white cast iron. In its state of perfection, white cast iron has a silver color, and a bright metallic lustre. It is employed frequently in Germany for the manufacture of steel, and is then called *steel floss*, or *lamellar floss*, a title which it still retains, though it be hardly silver white, and have ceased to be foliated. When its color takes a bluish-gray tinge, and its fracture appears striated or splintery, or when it exhibits gray spots, it is then styled *flower floss*. In a third species of white cast iron we observe still much lustre, but its color verges upon gray, and its texture is variable. Its fracture has been sometimes compared to that of a broken cheese. This variety occurs very frequently. It is a white cast iron, made by a surcharge of ore in the furnace. If the white color becomes less clear and turns bluish, if its fracture be contorted, and contains a great many empty spaces or air-cells, the metal takes the name of *cavernous-floss*, or *tender-floss*. The whitest metal cannot be employed for casting. When the white is mixed with the gray cast iron, it becomes *riband* or *trout* cast iron.

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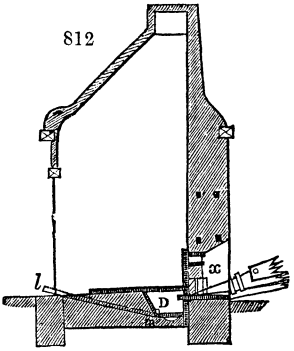

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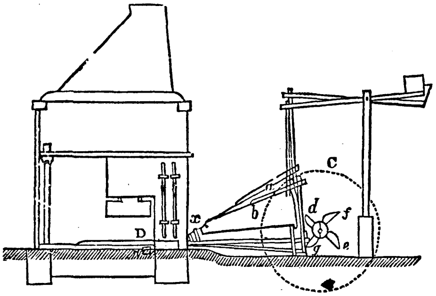

The German refining forge.—*Figs.* 812, 813 represent one of the numerous refinery furnaces so common in the Hartz. The example is taken from the *Mandelholz* works, in the neighborhood of Elbingerode. *Fig.* 813 is an elevation of this forge. D is the refinery hearth, provided with two pairs of bellows. *Fig.* 812 is a vertical section, showing particularly the construction of the crucible or hearth in the refinery forge D. C is an overshot water wheel, which gives an alternate impulsion to the two bellows *a b* by means of the revolving shaft *c*, and the cams or tappets *d f e g*.

D, the hearth, is lined with cast iron plates. Through the pipe *l*, cold water may be introduced, under the bottom plate *m*, in order to keep down, when necessary, the temperature of the crucible, and facilitate the solidification of the *loupe* or *bloom*. An orifice *n*, *figs*. 812, 813, called the *chio* (floss hole), allows the melted slag or cinder to flow off from the surface of the melted metal. The copper pipe or nose piece *p*, *fig*. 811, conducts the blast of both bellows into the hearth, as shown at *b x*, *fig*. 813, and D *g p*, *fig*. 811.

The substance subjected to this mode of refinery, is a gray carbonaceous cast iron, from the works of Rothehütte. The hearth D, being filled and heaped over with live charcoal, upon the side opposite to the tuyère *x*, *figs*. 812, 813, long pigs of cast iron are laid with their ends sloping downwards, and are drawn forwards successively into the hearth by a hooked poker, so that the extremity of each may be plunged into the middle of the fire, at a distance of 6 or 8 inches from the mouth of the tuyère. The workman proceeds in this way, till he has melted enough of metal to form a *loupe*. The cast iron, on melting, falls down in drops to the bottom of the hearth; being covered by the fused slags, or vitreous matters more or less loaded with oxyde of iron. After running them off by the orifice *n*, he then works the cast iron by powerful stirring with an iron rake (*ringard*), till it is converted into a mass of a pasty consistence.

During this operation, a portion of the carbon contained in the cast iron combines with the atmospherical oxygen supplied by the bellows, and passes off in the form of carbonic oxyde and carbonic acid. When the lump is coagulated sufficiently, the workman turns it over in the hearth, then increases the heat so as to melt it afresh, meanwhile exposing it all round to the blast, in order to consume the remainder of the carbon, that is, till the iron has become ductile, or refined. If one fusion should prove inadequate to this effect, two are given. Before the conclusion, the workman runs off a second stratum of vitreous slag, but at a higher level, so that some of it may remain upon the metal.

The weight of such a *loupe* or *bloom* is about 2 cwts., being the product of 2 cwts. and $\frac{7}{10}$ of pig iron; the loss of weight is therefore about 26 per cent. 149 pounds of charcoal are consumed for every 100 pounds of bar iron obtained. The whole operation lasts about 5 hours. The bellows are stopped as soon as the bloom is ready; this is immediately transferred to a forge hammer, such as is represented *fig*. 816; the cast iron head of which weighs 8 or 9 cwts. The bloom is greatly condensed thereby, and discharges a considerable quantity of semi-fluid cinder. The lump is then divided by the hammer and a chisel into 4 or 6 pieces, which are reheated, one after another, in the same refinery fire, in order to be forged into bars, while another pig of cast iron is laid in its place, to prepare for the formation of a new bloom. The above process is called by the Germans *klump-frischen*, or lump-refining. It differs from the *durch-brech-frischen*, because in the latter, the lump is not turned over in mass, but is broken, and exposed in separate pieces successively to the refining power of the blast near the tuyère. The French call this *affinage par portions ;* it is much lighter work than the other.

The quality of the iron is tried in various ways; as first, by raising a bar by one end, with the two hands over one's head, and bringing it forcibly down to strike across a narrow anvil at its centre of percussion, or one third from the other extremity of the bar; after which it may be bent backwards and forwards at the place of percussion several times; 2. a heavy bar may be laid obliquely over props near its end, and struck strongly with a hammer with a narrow pane, so as to curve it in opposite directions; or while heated to redness, they may be kneed backwards and forwards at the same spot, on the edge of the anvil. This is a severe trial, which the hoop L, Swedish iron, bears surprisingly, emitting as it is hammered, a phosphoric odor, peculiar to it and to the bar iron of Ulverstone, which also resembles it, in furnishing a good steel. The forging of a horse-shoe is reckoned a good criterion of the quality of iron. Its freedom from flaws is detected by the above modes; and its linear strength may be determined by suspending a scale to the lower end of a hard-drawn wire, of a given size, and adding weights till the wire breaks. The treatises of Barlow and Tredgold may be consulted with advantage on the methods of proving the strength of different kinds of iron, in a great variety of circumstances.

Steel of cementation, or blistered steel and cast steel, are treated under the article Steel. But since in the conversion of cast iron into wrought iron, by a very slight difference in the manipulations, a species of steel may be produced called *natural steel*, I shall describe this process here.

Fig. 814 is a view of the celebrated steel iron works, called Königshütte, (*king's-forge*), in Upper Silesia, being one of the best arranged in Germany, for smelting iron ore by means of coke. The front shown here is about 400 English feet long. *a a* are two blast furnaces. A third blast furnace, all like the English, is situated to the left of one of the towers *b*. *b b* are the charging towers, into which the ore is raised by machinery from the level of the store-houses *l l*, up to the mouth of the furnaces *a a ; c c* point to the positions of the boilers of the two steam engines, which drive two cylinder bellows at *f*. *n n n n* are arched cellars placed below the store-houses *l l*, for containing materials and tools necessary for the establishment.

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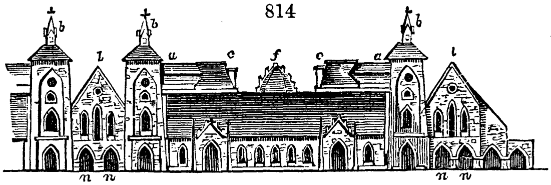
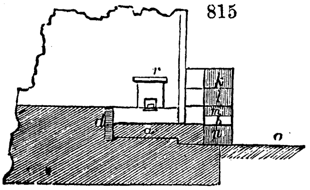


Figs. 810, 815, are vertical sections of the forge of Königshütte, for making natural steel; *fig.* 810 being drawn in the line A B of the plan, *fig.* 811. *a* is the bottom of the hearth, consisting of a fire-proof gritstone; *b* is a space filled with small charcoal, damped with water, under which, at *n*, in *fig.* 815, is a bed of well rammed clay; *d* is a plate of cast iron, which lines the side of the hearth called ruckstein (backstone) in German, and corrupted by the French into *rustine ; f* is the plate of the counter-blast; *g* the plate of the side of the tuyère; behind, upon the face *d*, the fire-place or hearth is only 5½ inches deep; in front as well as upon the lateral faces, it is 18 inches deep. By means of a mound made of dry charcoal, the posterior face *d* is raised to the height of the face *f*. *i*, *fig.* 811, is the floss-hole, by which the slags are run off from the hearth during the working, and through which, by removing some bricks, the lump of steel is taken out when finished.

815



k l m are pieces of cast iron, for confining the fire in front, that is, towards the side where the workman stands; *o* is the level of the floor of the works; *p* a copper tuyère; it is situated 4½ inches above the bottom *a*, slopes 5 degrees towards it, and advances 4 inches into the hearth or fire-place, where it presents an orifice, one half inch in horizontal length, and one inch up and down; *q* the nose pipes of two bellows, like those represented in *fig.* 813, and under Silver; the round orifice of each of them within the tuyère being one inch in diameter. *r* is the lintel or top arch of the tuyère, beneath which is seen the cross section of the pig of cast iron under operation.

For the production of natural steel, a white cast iron is preferred, which contains little carbon, which does not flow thin, and which being cemented *over or above the wind,* falls down at once through the blast to the bottom of the hearth in the state of steel. With this view, a very flat fire is used; and should the metal run too fluid, some malleable lumps are introduced to give the mass a thicker pasty consistence.

If the natural steel be supposed to contain too little carbon, which is a very rare case, the metal bath covered with its cinder slag, is diligently stirred with a wooden pole, or it may receive a little of the more highly carbureted iron. If it contains the right dose of carbon, the earthy and other foreign matters are made progressively to sweat out, into the supernatant slag. When the mass is found by the trial of a sample to be completely converted, and has acquired the requisite stiffness, it is lifted out of the furnace, by the opening in front, subjected to the forge hammer, and drawn into bars. In Sweden, the cast iron pigs are heated to a cherry-red, and in this state broken to pieces under the hammer, before they are exposed in the steel furnace. These natural steels are much employed on the Continent in making agricultural implements, on account of their cheapness. The natural steel of Styria is regarded as a very good article.

Wootz is a natural steel prepared from a black ore of iron in Hindostan, by a process analogous to that of the Catalan hearth, but still simpler. It seems to contain a minute portion of the combustible bases of alumina and silica, to which its peculiar hardness when tempered may possibly be ascribed. It is remarkable for the property of assuming a damask surface, by the action of dilute sulphuric acid, after it has been forged and polished. See Damascus and Steel.

Fig. 816 is the German forge-hammer; to the left of 1, is the axis of the rotatory cam, 2, 3, consisting of 8 sides, each formed of a strong broad bar of cast iron, which are joined together to make the octagon wheel. 4, 5, 6, are cast iron binding rings or hoops, made fast by wooden wedges. *b, b,* are standards of the frame-work *e, l, m,* in which the helve of the forge-hammer has its fulcrum near *u*. *h*, the sole part of the frame. Another cast iron base or sole is seen at *m*. *n* is a strong stay, to strengthen the frame-work. At *r* two parallel hammers are placed, with cast-iron heads and wooden helves. *s* is the anvil, a very massive piece of cast iron. *t* is the end of a vibrating beam, for throwing back the hammer from it forcibly by recoil. *x y* is the outline of the water-wheel which drives the whole. The cams or tappets are shown mounted upon the wheel 6, *g*, 6.

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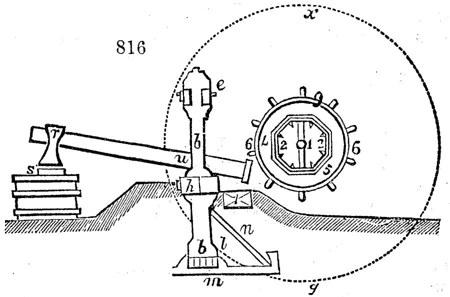

Analysis of irons.—Oxydized substances cannot exist in metallic iron, and the foreign substances it does contain are present in such small quantities, that it is somewhat difficult to determine their amount. The most intricate point is, the proportion of carbon. The free carbon, which is present only in gray cast iron, may, indeed, be determined nearly, for most of it remains after solution of the metal in acids. The combined charcoal, however, changes by the action of muriatic acid into gas and oil; sulphuric acid also occasions a great loss of carbon, and nitric acid dissipates it almost entirely. Either nitre or chloride of silver may be employed to ascertain the amount of carbon; but when the iron contains chromium and much phosphorus, the determination of the carbon is attended with many difficulties.

The quantity of sulphur is always so small, that it can scarcely be ascertained by the weight of the precipitate of sulphate of barytes from the solution of the iron in nitro-muriatic acid. The iron should be dissolved in muriatic acid; and the hydrogen, as it escapes charged with the sulphur, should be passed through an acidulous solution of acetate of lead. The weight of the precipitated sulphuret shows the amount of sulphur, allowing 13·45 of the latter for 100 of the former. In this experiment the metal should be slowly acted upon by the acid. Cast iron takes from 10 to 15 days to dissolve, steel from 8 to 10, and malleable iron 4 days. The residuum of a black color does not contain a trace of sulphur.

Phosphorus and chromium are determined in the following way. The iron must be dissolved in nitro-muriatic acid, to oxygenate those two bodies. The solution must be evaporated cautiously to dryness in porcelain capsules, and the saline residuum heated to redness. A little chloride of iron is volatilized, and the remainder resembles the red-brown oxyde. This must be mixed with thrice its weight of carbonate of potash, and fused in a platinum crucible; the quantity of iron being from 40 to 50 grains at most.

The mixture, after being acted upon by boiling water, is to be left to settle, to allow the oxyde to be deposited, for it is so fine as to pass through a filter. If the iron contained manganese, this would be found *at first* in the alkaline solution; but manganese spontaneously separates by exposure to the air. The alkaline liquor must be supersaturated with muriatic acid, and evaporated to dryness. The liquor acidulated, and deprived of its silica by filtration, is to be supersaturated with ammonia; when the alumina will precipitate in the state of a subphosphate. When the liquor is now supersaturated with acetic acid, and then treated with acetate of lead, a precipitate of phosphate of lead almost always falls. There is hardly a bit of iron to be found which does not contain phosphorus. The slightest trace of chrome is detected by the yellow color of the lead precipitate; if this be white there is none of the coloring metal present.

100 parts of the precipitated phosphate of lead contain, after calcination, 19·4 parts of phosphoric acid. The precipitate should be previously washed with acetic acid, and then with water. These 19·4 parts contain 8·525 parts of phosphorus.

Cast iron sometimes contains calcium and barium, which may be detected by their well-known reagents, oxalate of ammonia. and sulphuric acid. In malleable iron they are seldom or never present.

The charcoal found in the residuum of the nitro-muriatic solution is to be burned away under a muffle. The solution itself contains along with the oxyde of iron, protoxyde of manganese, and other oxydes, as well as the earths, and the phosphoric and arsenic acids. Tartaric acid is to be added to it, till no precipitate be formed by supersaturation with caustic ammonia. The ammoniacal liquor must be treated with hydrosulphuret of ammonia as long as it is clouded, then thrown upon a filter. The precipitate is usually very voluminous, and must be well washed. The liquor which passes through is to be saturated with muriatic acid, to decompose all the sulphurets.

The solution still contains all the earths and the oxyde of titanium, besides the phosphoric acid. It is to be evaporated to dryness, whereby the ammonia is expelled, and the carbonaceous residuum must be burned under a muffle. If the iron contains much phosphorus, the ashes are strongly agglutinated. They are to be fused as already described along with carbonate of potash, and the mass is to be treated with boiling water. The residuum may be examined for silica, lime, barytes, and oxyde of titanium. Muriatic acid being digested on it, then evaporated to dryness, and the residuum treated with water, will leave the silica. Caustic ammonia, poured into the solution, will separate the alumina, if any be present, and the oxyde of titanium; but the former almost never occurs.

Manganese is best sought for by a distinct operation. The iron must be dissolved at the heat of boiling water, in nitro-muriatic acid; and the solution, when very cold, is to be treated with small successive doses of solution of carbonate of ammonia. If the iron has been oxydized to a maximum, and if the liquor has been sufficiently acid, and diluted with water, it will retain the whole of the manganese. This process is as good as that by succinate of ammonia, which requires many precautions.

The liquor is often tinged yellow by carbon, after it has ceased to contain a single trace of iron oxyde. As soon as litmus paper begins to be blued by carbonate of ammonia, we should stop adding it; immediately throw the whole upon a filter, and wash continuously with cold water. What passes through is to be neutralized with muriatic acid, and concentrated by evaporation. It may contain, besides manganese, some lime or barytes. It should therefore be precipitated with hydro-sulphuret of ammonia, the hydrosulphuret of manganese should be collected, dissolved in strong muriatic acid, filtered, and treated, at a boiling heat, with carbonate of potash. The precipitate, well washed and calcined, contains, in 100 parts, 72·75 parts of metallic manganese.

The copper, arsenic, lead, tin, bismuth, antimony, or silver, are best separated by a stream of sulphureted hydrogen gas passed through the solution in nitro-muriatic acid, after it is largely diluted with water. The precipitate must be cautiously roasted in a porcelain test, to burn away the large quantity of sulphur which is deposited in consequence of the conversion of the peroxyde of iron into the protoxyde. If nothing remains upon the test, none of these metals is present. If a residuum be obtained, it must be dissolved in nitro-muriatic acid, and subjected to examination. But, in fact, carbon, sulphur, phosphorus, silicon, and manganese, are the chief contaminators of iron.

Chloride of silver affords the means of determining the proportion of carbon contained in iron and of ascertaining the state in which that substance exists in the metal. Fused

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chloride of a pale yellow color must be employed. The operation is to be performed in close vessels, with the addition of a great deal of water, and a few drops of muriatic acid. The carbonaceous residuum is occasionally slightly acted upon. We may judge of this circumstance by the gases disengaged, as well as by the appearance of the charcoal.

Ductile iron and soft steel, as well as white cast-iron which has been rendered gray by roasting, when decomposed by chloride of silver, afford a blackish-brown unmagnetic charcoal, and a plumbaginous substance perfectly similar to what is extracted from the same kinds of iron, by solution in acids. A portion of this plumbago is also converted into charcoal of a blackish brown color, by the action of the chloride. Hence this agent does not afford the means of obtaining what has been called the poly-carburet, till it has produced a previous decomposition. But we obtain it, in this manner, purer and in greater quantity than we could by dissolving the metal in the acids. The only subject of regret is, that we possess no good criterion for judging of the progress of this analytical operation.

Gray cast iron leaves, besides the poly-carburet, a residuum of plumbago, and carbon which was not chemically combined with the iron; while tempered steel and white cast iron afford merely a blackish brown charcoal; but the operation is extremely slow with the latter two bodies, because a layer of charcoal forms upon the surface, which obstructs their oxydizement. For this reason the white cast iron ought to be previously changed into gray by fusion in a crucible lined with charcoal, before being subjected to the chloride of silver; if this process be employed for tempered steel, the combined carbon becomes merely a poly-carburet. It would not be possible to operate upon more than 15 grains, which require from 60 to 80 times that quantity of the chloride, and a period of 15 days for the experiment.

The residuum, which is separable from the silver only by mechanical means, should be dried a long time at the heat of boiling water. It contains almost always iron and silica. After its weight is ascertained, it is to be burned in a crucible of platinum till the ashes no longer change their color, and are not attractable by the magnet. The difference between the weights of the dried and calcined residuum is the weight of the charcoal. The oxyde of iron is afterwards separated from the silica by muriatic acid.

In operating upon gray cast iron, we should ascertain separately the proportion of graphite or plumbago, and that of the combined charcoal. To determine the former, we dissolve a second quantity of the cast iron in nitric acid, with a little muriatic; the residuum, which is graphite, is separated from the silica and the combined carbon by the action of caustic potash. After being washed and dried, it must be weighed. The weight of the graphite obtained being deducted from the quantity of carbon resulting from the decomposition effected by the chloride of silver, the remainder is the amount of the chemically combined carbon.

By employing muriatic acid, we could dissipate at once the combined carbon; but this method would be inexact, because the hydrogen disengaged would carry off a portion of the graphite.

According to Karsten, Mushet's table of the quantities of carbon contained in different steels and cast irons is altogether erroneous. It gives no explanation why, with equal proportions of charcoal, cast iron constitutes at one time a gray, soft, granular metal, and at another, a white, hard, brittle metal in lamellar facets. The incorrectness of Mushet's statement becomes most manifest when we see the white lamellar cast iron melted in a crucible lined with charcoal, take no increase of weight, while the gray cast iron treated in the same way becomes considerably heavier.

Analysis has never detected a trace of carbon *unaltered* or of graphite in white cast iron, if it did not proceed from small quantities of the gray mixed with it; while perfect gray cast iron affords always a much smaller quantity of carbon altered by combination, and a much greater quantity of graphite. Neither kind of cast iron, however, betrays the presence of any oxygen. Steel affords merely altered carbon, without graphite; the same thing holds true of malleable iron; while the iron obtained by fusion with 25 per cent. of scales of iron contains no carbon at all.

The graphite of cast iron is obtained in scales of a metallic aspect, whereas the combined carbon is obtained in a fine powder. When the white cast iron has been roasted, and become gray, and is as malleable as the softest gray cast iron, it still affords no graphite as the latter does, though in appearance both are alike. Yet in their properties they are still essentially dissimilar.

With 4¼ per cent. of carbon, the white cast iron preserves its lamellar texture; but with less carbon, it becomes granular and of a gray color, growing paler as the dose of carbon is diminished, while the metal, after passing through an indefinite number of gradations, becomes steely cast iron, very hard steel, soft steel, and steely wrought iron.

The steels of the forge and the cast steels examined by Karsten, afforded him from

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2·3 to 1¼ per cent. of carbon; in the steel of cementation (blistered steel), he never found above 1¾ of carbon. Some wrought irons which ought to contain no charcoal, hold as much as ½ per cent. and they then approach to steel in nature. The softest and purest irons contain still 0·2 per cent. of carbon.

The quantity of graphite which gray cast-iron contains, varies, according to Karsten's experiments, from 2·57 to 3·75 per cent.; but it contains, besides, some carbon in a state of alteration. The total contents in carbon varied from 3·15 to 4·65 per cent. When the congelation of melted iron is very slow, the carbon separates, probably in consequence of its crystallizing force, so as to form a gray cast-iron replete with plumbago. If the gray do not contain more charcoal than the white from which it has been formed, and if it contain the charcoal in the state of mechanical mixture, then it can have little or none in a state of combination, even much less than what some steels contain. Hence we can account for some of its peculiarities in reference to white cast-iron; such as its granular texture, its moderate hardness, the length of time it requires to receive annealing colors, the modifications it experiences by contact of air at elevated temperatures, the high degree of heat requisite to fuse it, its liquidity, and finally its tendency to rust by porosity, much faster than the white cast-iron.

We thus see that carbon may combine with iron in several manners; that the gray cast-iron is a mixture of steely iron and plumbago; that the white, rendered gray and soft by roasting, is a compound of steely iron and a carburet of iron, in which the carbon predominates; and that untempered steel is in the same predicament.

For the following analyses of cast-irons, we are indebted to MM. Gay Lussac and Wilson.

TABLE.—In 100 parts.

Cast-iron.	Iron.	Carbon.	Silica.	Phosphorus.	Manganese.	Remarks.
White cast from Siegen	94·338	2·690	0·230	0·162	2·590	By wood charcoal.
Do. Coblentz -	94·654	2·441	0·230	0·185	2·490	do.
Do. a. d. Champ	96·133	2·324	0·840	0·703	a trace	do.
Do. Isère - -	94·687	2·636	0·260	0·280	2·137	do.
Gray Nivernais -	95·673	2·254	1·030	1·043	a trace	do.
Do. Berry - -	95·573	2·319	1·920	0·188	do.	Mixt'e of coke & do.
Do. a. d. Champ	95·971	2·100	1·060	0·869	do.	Charcoal.
Do. Creusot -	93·385	2·021	3·490	0·604	do.	Coke.
Do. a. d. Franche Comté -	95·689	2·800	1·160	0·351	do.	do.
Do. Wales - -	94·842	1·666	3·000	0·492	do.	do.
Do. Do. - - -	95·310	2·550	1·200	0·440	do.	do.
Do. Do. - - -	95·150	2·450	1·620	0·780	do.	do.

Karsten has given the following results as to carbon, in 100 parts of gray cast-iron.

Gray cast-iron.	Combined carbon.	Free carbon.	Total. carbon.	Remarks.
Siegen, from brown iron stone -	0·89	3·71	4·60	By wood charcoal.
Siegen (Widderstein), from brown and sparry iron - - - - -	1·03	3·62	4·65	do.
Malapane, from spherosiderite -	0·75	3·15	3·90	do.
Königshütte, from brown ore -	0·58	2·57	3·15	coke.
Do. at a lower smelting heat - -	0·95	2·70	3·65	do.

IRON, Cast, Strength of.—In the following Table each bar is reduced to exact one square inch; and the transverse strength, which may be taken as a criterion the value of each iron, is obtained from a mean between the experiments upon i (*Memoirs of Brit. Ass.*) first on bars 4 ft. 6 in. between the supports, and next those of half the length, or 2 ft. 3 in. between the supports. All the other results are deduced from the 4 ft. 6 in. bars. In all cases the weights were laid on the middle of the bar.

Table of Results obtained from Experiments on the Strength and other Properties of Cast Iron, from the principal Iron Works in the United Kingdom. By Mr. Wm. Fairbairn.

Number of Iron in the scale of strength.	Names of Irons	Number of Experiments on each.	Specific gravity.	Modulus of elasticity in lbs. per square inch, or stiffness.†	Breaking weight in lbs. of bars 4 ft. 6 in. between supports.	Breaking weight in lbs. of bars 2 ft. 3 in. reduced to 4 ft. 6 in. between supports.	Mean breaking weight in lbs. (S.)	Ultimate deflection of 4 ft. 6 in. bars, in parts of an inch.	Power of the 4 ft. 6 in. bars to resist impact.	Color.	Quality
1	Ponkey, No. 3. Cold Blast - - -	4	7·122	17211000	567	595	581	1·747	992	Whitish gray	Hard.
2	Devon, No. 3. Hot Blast* - - -	2	7·251	22473650	537	—	537	1·09	589	White - -	Hard.
3	Oldberry, No. 3. Hot Blast - -	5	7·300	22733400	543	517	530	1·005	549	White - -	Hard.
4	Carron, No. 3. Hot Blast* - -	2	7·056	17873100	520	534	527	1·365	710	Whitish gray	Hard.
5	Beaufort, No. 3. Hot Blast - - -	5	7·069	16802000	505	529	517	1·599	807	Dullish gray	Hard.
6	Butterley - - - - - - - - -	4	7·038	15379500	489	515	502	1·815	889	Dark gray -	Soft.
7	Bute, No. 1. Cold Blast - - -	4	7·066	15163000	495	487	491	1·764	872	Bluish gray	Soft.
8	Wind Mill End, No. 2. Cold Blast	4	7·071	16490000	483	495	489	1·581	765	Dark gray -	Hard.
9	Old Park, No. 2. Cold Blast - -	5	7·049	14607000	441	529	485	1·621	718	Gray - - -	Soft.
10	Beaufort, No. 2. Hot Blast - -	4	7·108	16301000	478	470	474	1·512	729	Dull gray -	Hard.
11	Low Moor, No. 2. Cold Blast - -	4	7·055	14509500	462	483	472	1·852	855	Dark gray -	Soft.
12	Buffery, No. 1. Cold Blast* - -	5	7·079	15381200	463	—	463	1·55	721	Gray - - -	Rather hard.
13	Brimbo, No. 2. Cold Blast - - -	5	7·017	14911666	466	453	459	1·748	815	Light gray -	Rather hard.
14	Apedale, No. 2. Hot Blast - -	3	7·017	14852000	457	455	456	1·730	791	Light gray -	Stiff.
15	Oldberry, No. 2. Cold Blast - -	4	7·059	14307500	453	457	455	1·811	822	Dark gray -	Rather soft.
16	Pentwyn, No. 2. - - - - - - -	4	7·038	15193000	438	473	455	1·484	650	Bluish gray	Hard.
17	Maesteg, No. 2. - - - - - -	5	7·038	13959500	453	455	454	1·957	886	Dark gray -	Rather soft.
18	Muirkirk, No. 1. Cold Blast* - -	4	7·113	14003550	443	464	453	1·734	770	Bright gray	Fluid.
19	Adelphi, No. 2. Cold Blast - -	5	7·080	13815500	441	457	449	1·759	777	Light gray -	Soft.
20	Blania, No. 3. Cold Blast - - -	5	7·159	14281466	433	464	448	1·726	747	Bright gray	Hard.
21	Devon, No. 3. Cold Blast* - -	4	7·285	22907700	448	—	448	·790	753	Light gray -	Hard.
22	Gartsherrie, No. 3. Hot Blast -	5	7·017	13894000	427	467	447	1·557	998	Light gray -	Soft.
23	Frood, No. 2. Cold Blast - - -	5	7·031	13112666	460	434	447	1·825	841	Light gray -	Open.
24	Lane End, No. 2. - - - - - -	3	7·028	15787666	444	—	444	1·414	629	Dark gray -	Soft.
25	Carron, No. 3. Cold Blast* - - -	5	7·094	16246966	444	443	443	1·336	593	Gray - - -	Soft.
26	Dundivan, No. 3. Cold Blast	4	7·087	16534000	456	430	443	1·469	674	Dull gray -	Rather soft.
27	Maesteg (Marked Red) -	5	7·038	13971500	440	444	442	1·887	830	Bluish gray	Fluid.
28	Corbyns Hall, No. 2. -	5	7·007	13845866	430	454	442	1·687	727	Gray - - -	Soft.
29	Pontypool, No. 2. - - - -	5	7·080	13136500	439	441	440	1·857	816	Dull blue -	Rather soft.
30	Wallbrook, No. 3. - - -	5	6·979	15394766	432	449	440	1·443	625	Light gray -	Rather hard.
31	Milton, No. 3. Hot Blast - - -	4	7·051	15852500	427	449	438	1·368	585	Gray - -	Rather hard.
32	Buffery, No. 1. Hot Blast* - -	3	6·998	13730500	436	—	436	1·64	721	Dull gray -	Soft.
33	Level, No. 1. Hot Blast - - - -	5	7·080	15452500	461	403	432	1·516	699	Light gray -	Soft.
34	Pant, No. 2. - - - - - - - - -	5	6·975	15280900	408	455	431	1·251	511	Light gray -	Rather hard.
35	Level, No. 2. Hot Blast - - - -	6	7·031	15241000	419	439	429	1·358	570	Dull gray -	Soft.
36	W. S. S., No. 2. - - - - - - -	5	7·041	14953333	413	446	429	1·339	554	Light gray -	Soft.
37	Eagle Foundry, No. 2. Hot Blast	4	7·038	14211000	408	446	427	1·512	618	Bluish gray	Soft.
38	Elsicar, No. 2. Cold Blast - -	4	6·928	12586500	446	408	427	2·224	992	Gray - -	Soft.
39	Varteg, No. 2. Hot Blast - - -	4	7·007	15012000	422	430	426	1·450	621	Gray - - -	Hard.
40	Coltham, No. 1. Hot Blast -	5	7·128	15510066	464	385	424	1·532	716	Whitish gray	Rather soft.
41	Carroll, No. 2 Cold Blast - - -	4	7·069	17036000	430	408	419	1·231	530	Gray - - -	Hard.
42	Muirkirk, No. 1. Hot Blast* - -	4	6·953	13294400	417	419	418	1·570	656	Bluish gray	Soft.
43	Bierley, No. 2. - - - - - - -	5	7·185	16156133	404	432	418	1·222	494	Dark gray -	Soft.
44	Coed-Talon, No. 2. Hot Blast* -	4	6·969	14322500	409	424	416	1·882	771	Bright gray	Soft.
45	Coed-Talon, No. 2. Cold Blast*	5	6·955	14304000	408	418	413	1·470	600	Gray - - -	Rather soft.
46	Monkland, No. 2. Hot Blast - -	3	6·916	12259500	402	404	403	1·762	709	Bluish gray	Soft.
47	Ley's Works, No. 1. Hot Blast -	3	6·957	11539333	392	—	392	1·890	742	Bluish gray	Soft.
48	Milton, No. 1. Hot Blast - - -	4	6·976	11974500	353	386	369	1·525	538	Gray - - -	Soft and fluid.
49	Plaskynaston, No. 2. Hot Blast -	5	6 916	13341633	378	337	357	1·366	517	Light gray	Rather soft.

Rule.—To find from the above table the breaking weight in rectangular bars, generally, calling b and d the breadth and depth in inches, and l the distance between the supports in feet, and putting 4·5 for 4 ft. 6 in., we have $\frac{4\cdot5 \times bd^2S}{l}$ = breaking weight in lbs., the value of S being taken from the table above.

For example:—What weight would be necessary to break a bar of Low Moor iron, 2 inches broad, 3 inches deep, and 6 feet between the supports? According to

Analyses of Ten Specimens of Cast Iron made from South Staffordshire Iron Ore, Wes of Dudley.

Iron from Hot Blast.

	I.	II.	III.	IV.	V.	VI.
Iron - - - - -	89.53	92·98	93·84	92·90	C(a)95·23	95·80
Carbon - - - -	C 3·27 7·93	C 3·11 6·51	C 2·98 5·54	C 0·87 6·83	C(b) 1·77	2·72
Carbon - - - -	- - -	- - -	- - -	- - -	0·49	0·26
Silica, &c. - - -	- - -	- - -	- - -	- - -	0·31	0.11
Manganese - - -	1·71	1·30	0·72	0·62	0·34	0·54
Calcium - - -	0·11	trace	0.34	0·06	0·10	0·06
Sodium - - -	0·41	0.37	0.39	0·30	0·19	0·14
Potassium - - -	- - -	- - -	trace	trace		
Sulphur - -	0·07	trace	minute trace	trace	trace	trace
Phosphorus - -	0·54	lost	0·07	0·40	0·12	0·37
	100·39	100·19	100·90	101.11	98·55	100·00

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* The irons with asterisks are taken from the experiments on hot and cold blast iron, made by Mr Hodgkinson and myself for the British Association for the Advancement of Science.—See Seventh Report, vol. vi.

† The modulus of elasticity was usually taken from the deflection caused by 112 lbs. on the 4 ft. in. bars.

Iron from Cold Blast.

	I.	III.	IV.	·	V.
Iron - - - - - - - - -	94·10	96·57	94·53	- -	94·42
Combined carbon (a) - -	1·87	0·95			
Uncombined carbon (b) -	1·92	1·67	C 1·98 3·71	C 2·73	4.05
Silica - - - - - - - -	1·30	0·51			
Manganese - - - - -	1·12	1·16	0·33	- -	0·94
Cobalt - - - - - - -	trace	- -	- -	- -	trace
Chromium - - - - - -	trace				
Calcium - - - - - -	0·05	trace	0·25	- -	0·16
Sodium - - - - - - -	0·15	trace	0·30	- -	0·34
Potassium - - - - - -	trace	0·42			
Sulphur - - - - - - -	trace	0·11	0·05	- -	trace
Phosphorus - - - - - -	0·21	0·36	0·03	- -	0·36
	100·73	101·75	99·20	- -	100·27

the rule given above, we have $b = 2$ inches, $d = 3$ inches, $l = 6$ feet, $S = 472$ from the table. Then $\frac{4·5 \times b\,d^2 S}{l} = \frac{4·5 \times 2 \times 3^2 \times 472}{6} = 6372$ lbs., the breaking weight.

A very small amount of phosphorus is found to impart to iron a great degree of brittleness, when bar iron contains but 0·5 per cent.

Fig. 818. represents in section, and *fig.* 817. in plan, the famous cupola furnace for casting iron employed at the Royal Foundry in Berlin. It rests upon a foundation *a*, from 18 to 24 inches high, which supports the basement plate of cast iron, furnished with ledges, for binding the lower ends of the upright side plates or cylinder, *e*. Near the mouth there is a top-plate *d*, made in several pieces, which serves to bind the sides at their upper end, as also to cover in the walls of the shaft. These plates are most readily secured in their places by screws and bolts. Within this iron case, at a little distance from it, the proper furnace-shaft *e*, is built with fire-bricks, and the space between this and the iron is filled up with ashes. The sole of the hearth *f*, over the basement-plate, is composed of a mixture of fire-clay and quartz-sand firmly beat down to the thickness of 6 or 8 inches, with a slight slope towards the discharge-hole for running off the metal. *g* is the *form* or the tuyère (there are sometimes one on each side); *h* the nose pipe; the discharge aperture *i* is 12 inches wide and 15 inches high; across which the sole of the hearth is rammed down. During the melting operation this opening is filled up with fire-clay; when it is completed, a small hole merely is pierced through it at the lowest point, for running off the liquid metal. The hollow shaft should be somewhat wider at bottom than at top. Its dimensions vary with the magnitude of the foundry. When 5 feet high, its width at the level of the tuyère or blast hole may be from 20 to 22 inches. From 250 to 300 cubic feet of air per minute are required for the working of such a cupola. For running down 100 pounds of iron, after the furnace has been brought to its heat, 48 pounds of ordinary coke are used; but with the hot blast much less will suffice. The furnace requires feeding with alternate charges of coke and iron every 8 or 10 minutes. The waste of iron by oxidation and slag amounts in most foundries to fully 5 per cent. For carrying off the burnt air, a chimney-hood is commonly erected over the cupola. See FOUNDRY.

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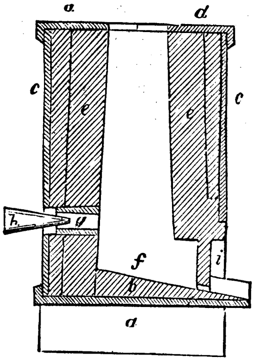

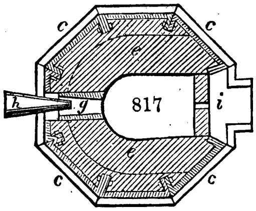

The double-arched air or wind-furnace used in the foundries in Staffordshire for melting cast iron, has been found advantageous in saving fuel, and preventing waste by slag. It requires fire-bricks of great size and the best composition.

The main central key-stone is constructed of large fire-bricks made on purpose; against that key-stone the two arches press, having their abutments at the sides against the walls. The highest point of the roof is only 8 inches above the melted metal. The sole of the hearth is composed of a layer of sand 8 inches thick, resting upon a bed of iron or of brickwork. The edge of the fire-bridge is only 3 inches above the fluid iron.

In from 2 to 4 hours from 1 to 3 tons of metal may be founded in such a furnace, according to its size; but it ought always to be heated to whiteness before the iron is introduced. 100 pounds of cast iron require from 1 to 1½ cubic foot of coal to melt them. The waste varies from 5 to 9 per cent.

I shall conclude the subject of iron with a few miscellaneous observations and statistical tables. Previously to the discovery by Mr. Cort, in 1785, of the methods of puddling and rolling or shingling iron, this country imported 70,000 tons of this metal from Russia and Sweden; an enormous quantity for the time, if we consider that the cotton and other automatic manufactures, which now consume so vast a quantity of iron, were then in their infancy. From the following table of the prices of bar iron in successive years, we may infer the successive rates of improvement and economy, with slight vicissitudes.

Years.	Per Ton.	Years.	Per Ton.
	£ s. £ s.		£ s. £ s.
1824	9 0 to 10 0	1830	5 5 to 6 0
1825	10 0 — 14 0	1831	5 5 — 5 10
1826	8 10 — 10 0	1832	5 0 — 5 10
1827	8 0 — 9 0	1833	5 10 — 6 0
1828	8 10 — 8 0	1834	6 0 — 6 10
1829	5 10 — 7 0	1835	5 10 — 7 0

The export of iron in 1836, in bars, rods, pigs, castings, wire, anchors, hoops, nails, and old iron, amounted to 189,390 tons; in unwrought steel to 3,014, and in cutlery to 21,072; in whole to 213,478; leaving apparently for internal consumption 776,522 tons, from which however one-tenth should probably be deducted for waste, in the conversion of the bar iron. Hence 700,000 tons may be taken as the approximate quantity of iron made use of in the United Kingdom, in the year 1836.

The years 1835 and 1836 being those of the railway mania over the world, produced a considerable temporary rise in the price of bar iron; but as this increased demand caused the construction of a great many more smelting and refining furnaces, it has tended eventually to lower the prices; an effect also to be ascribed to the more general use of the hot blast.

The exports of foreign produce in 1850 amounted to 5,996 tons, in 1851 to 4,813 tons; of British produce of all kinds (except steel) in 1850, 772,830 tons, in 1851 908,955 tons; the declared value being respectively 4,956,308*l.* and 5,414,121*l.* The imports in bars unwrought amounted in 1850 to 34,066 tons, and in 1851 to 40,279.

The relative cost of making cast iron at Merthyr Tydvil in South Wales, and at Glasgow, was as follows, eight or nine years ago.

At Merthyr.

	s.		*Tons.*	*Cwts.*	*Qrs.*	£	*s.*	*d.*
Raw mine at	10	per ton,	3	7	0	1	13	6
Coal at	6		2	16	0	0	16	6
Limestone			1	5	2	0	1	4
Other charges						0	9	1
Total Cost						3	0	5

At Glasgow.

	s.	*d.*	*Tons.*	*Cwts.*	£	*s.*	*d.*
Raw mine at	4	6	3	10	0	16	3
Splint coal at	2	5	5	15	0	14	0
Limestone at	0	3	0	14	0	3	6
Coals for the engine			1	10	0	3	0
Other charges					1	1	0
Total Cost					2	17	9

The cost is still nearly the same at Merthyr, but it has been greatly decreased at Glasgow.

The saving of fuel by the hot-blast is said to be in fact so great, that blowing cylinders, which were adequate merely to work three furnaces at the first period, were competent to work four furnaces at the last period. The saving of materials has moreover been accompanied by an increase of one-fourth in the quantity of iron, in the same time; as a furnace which turned out only 60 tons a week with the cold blast now turns out no less than 80 tons. That the iron so made is no worse, but probably better, when judiciously smelted, would appear from the following statement. A considerable order was not long since given to four iron-work companies in England, to supply pipes to one of the London water companies. Three of these supplied pipes made from the cold-blast iron; the fourth, it is said, supplied pipes made with the hot-blast iron. On subjecting these several sets of pipes to the requisite trials by hydraulic pressure, the last lot was found to stand the proof far better than any of the former three.—That iron was made with raw coal.

I have been since told by eminent iron-masters of Merthyr, that this statement stands in need of confirmation, or it is probably altogether apocryphal, and that as they find the hot blast weakens the iron, they will not adopt it.

Between the cast irons made in different parts of Great Britain, there are characteristic differences. The Staffordshire metal runs remarkably fluid, and makes fine sharp castings. The Welsh is strong, less fluent, but produces bar iron of superior quality. The Derbyshire iron also forms excellent castings, and may be worked with care into very good bar iron. The Scotch iron is very valuable for casting into hollow wares, as it affords a beautiful smooth skin from the moulds, so remarkable in the castings of the Carron company, in Stirlingshire, and of the Phœnix foundry, at Glasgow. The Shropshire iron resembles the Staffordshire in its good qualities.

The average quantity of fine metal obtainable from the forge-pigs at Merthyr Tydvil, from the finery furnace, is one ton for 22½ cwt. of cast iron, with a consumption of about 9½ cwt. of coal per ton.

Estimate of the average cost of erecting three blast furnaces.

BUILDING EXPENSES.	
Foundations	£480
Masonry of hewn grit-stones	600
Common bricklayers' work	1200
Lining of the furnace, hearth, &c., in fire-bricks	1140
Fire-clay for building	80
Lime and sand	800
CAST IRON.	
Cast-iron pieces, such as dam-plates, tymp-plates, beams, tuyère-plates, &c., weighing about 24 tons for each furnace;—in whole	1140
WROUGHT IRON.	
For the binding-hoops, keys, &c.; 5 tons for each	300
COST OF LABOUR.	
Bricklayers, masons, and labourers in building	1080
VARIOUS EXPENSES.	
Scaffolding	48
Tools	160
Shed in front of each furnace	480
Terracing, cost of ground, &c.	2400
Total cost of erecting the furnaces	9908
INCIDENTAL CHARGES.	
Blowing machinery, and steam engine of 80-horse power	6400
Inclined railway for mounting the charges	120
Gallery for charging	160
Steam engine house	400
Carried forward	16,988

Brought forward	£16,988
Chimneys, boilers, &c.	480
Roasting kilns	480
Coke kilns	800
Dwelling houses for workmen	800
Total cost of 3 furnaces complete	£19,548

Estimate from the Neath-Abbey Works in S. Wales, of the cost of machines requisite for a forge and shingling mill, capable of turning out 120 *tons of bar iron per week.*

1. Steam-engine upon Bolton and Watt's construction; of 40 inches diameter in the cylinder, and 8-feet stroke; with boilers, pipes, grate, bars, fire-doors, &c. &c., complete	£1,600
2. System of great-geering for transmitting the crank-motion of the engine to the mill-work, with fly-wheel, &c.	1,090
3. A system of roughing rolls, with pinions, uprights, and every thing else necessary	525
4. Two pairs of finisher rolls, with all their accessories	525
5. Two pairs of shear-machines, at 170*l.* a-piece	340
6. One pair of rolls of 10 inches diameter, for making small bar iron, with all their accessories	230
7. Forge hammer, including the anvil, the cam-shafts, and all the other requisites	185
8. A complete turning lathe	200
	£4,695
9. To the above must be added, spare cylinders weighing about 60 tons	960
10. Duplicate articles for the steam-engine	?
11. 150 tons of cast-iron plates, to cover the floor of the mill	900
12. Eight tons of cast-iron pieces for a reverberatory furnace	52
13. Tools of malleable iron; rakes, oars, &c.	28
14. Castings for mounting a cupola furnace	50
15. Blowing machine for the cupola	80
16. Pieces of iron for a small forge, with two fires, two bellows, two anvils, iron tools faced with steel, and common iron tools, &c.	100
17. Eight tons of cast-iron pieces, and wrought-iron pieces for 14 puddling furnaces	983
18. Seven tons of cast-iron pieces, and wrought-iron for 4 re-heating furnaces	252
19. Tools for the puddlers and other workmen	15
20. Iron mountings for two cranes, partly made of wood	50
Total cost of machines, and pieces of iron	8165

To the above, the cost of the steam engine house is to be added, that of another forge hammer, and incidental expenses.

In Staffordshire the following estimate has been given:

A steam-engine of 60-horse power	2016
Rolls, with the iron-work of the furnaces, &c., to make 120 tons of bar iron weekly	2572
	4588

The Neath-Abbey estimate is greater, but that company has a high character for making substantial well-finished machinery.

Bar iron made entirely from ore without admixture of cinder, or vitrified oxide, is always reckoned worth 10*s.* a ton more than the average iron in the market, which is frequently made by smelting 25 per cent. of cinder with 75 of ore or *mine*, as it is called.

M. Virlet's Statistical Table of the Produce of Iron in Europe

	Quintals.
England (1827)	7,098,000
France (1834)	2,200,000
Russia (1834)	1,150,000
Austria (1829)	850,000
Sweden (1825)	850,000
Prussia	800,000

The Hartz Mountains	600,000
Holland and Belgium	600,000
Elba and Italy	280,000
Piedmont	200,000
Spain	180,000
Norway	150,000
Denmark	135,000
Bavaria	130,000
Saxony	80,000
Poland	75,000
Switzerland	30,000
Savoy	25,000
Total	13,433,000 (equal to about 672,000 tons.)

The gross annual production of iron in Great Britain is now upwards of 2,250,000 tons. Of this quantity South Wales furnishes 700,000, South Staffordshire, including Worcestershire, 600,000, and Scotland 600,000 tons. The remainder is divided among the several smaller districts. One of the principal causes of the advantages possessed by Great Britain in the manufacture of iron arises from the number and variety of the measures of argillaceous and black band ironstones which alternate with the beds of coal in almost all the coal fields; and in consequence of which, the same localities, and in many instances the same mineral workings, frequently furnish both the ore and the fuel to smelt it. So extensive are the ironstone beds of the coal measures that they furnish in themselves the greater part of the iron produced in Great Britain; but the iron-making resources of the kingdom are by no means confined to them. The carboniferous or mountain limestones of Lancashire, Cumberland, Durham, the Forest of Dean, Derbyshire, Somersetshire and South Wales, all furnish important beds and veins of hæmatite; those of Ulverstone, Whitehaven and the Forest of Dean, are the most extensively worked, and seem to be almost exhaustless. The brown hæmatites and white carbonates of Alston Moor and Weardale also exist in such large masses, that they must ultimately become of vast importance. In the older rocks of Devon and Cornwall are found important veins of black hæmatite, and in the granite of Dartmoor numerous veins of magnetic oxide and specular iron ore. The new red sandstone furnishes in its lowest measures beds of hæmatitic conglomerate. In the lias and oolites are important beds of argillaceous ironstones, now becoming extensively worked; and the iron ores of the green sand of Sussex, once the seat of a considerable manufacture of iron, will in all probability soon again become available by means of the facilities of railway communication.

In the following classification the number of the blast furnaces in each district is given, and the ironstone of the coal measures are arranged in the definite order in which they occur in the different coal fields; so that their position in reference to the beds of coal alternating with them is at once seen. The more important of the coal fields are also subdivided into districts showing the changes which occur in each, and thus giving a concise view of their general character.

The produce of the iron manufacture in Great Britain in 1750 was only about 30,000 tons; in 1800 it had increased to 180,000 tons; in 1825 to 600,000 tons. See Metallic Statistics.

IRON, PRODUCTION OF.

South Wales. (*Eastern Outcrop.*)

Principal Works:—	Blast Furnaces. In.	Blast Furnaces. Out.
Cwm Bran	0	1
Pontypool	2	1
Abersychan	2	4
Pentwyn	0	3
Vateg	2	0
Gelynos	3	0
Blaenavon	3	2
23 Furnaces	**12**	**11**

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SOUTH WALES. (*North Eastern Outcrop.*)

Principal Works:—	Blast Furnaces. In.	Blast Furnaces. Out.
Clydach	4	0
Nant-y-glo	7	1
Coalbrook Vale	2	3
Blaina	2	1
Cwm Celyn	2	1
Beaufort	7	0
Ebbw Vale	4	0
Victoria	2	2
Sirhowey	5	0
Tredegar	7	0
50 Furnaces	42	8

The beds of coal in this division of the coal-field are all bituminous. The principal coals only are given in this section. The iron stones are principally argillaceous, although some important beds of blackband or carbonaceous ironstone exist locally. The total thickness of the coal measures, in this series, from the Soap Vein Mine to the bottom coal, is about 150 yards.

SOUTH WALES. (*Northern Outcrop.*)

Principal Works:—	Blast Furnaces. In.	Blast Furnaces. Out.
Rhymney	8	2
Dowlais	11	3
Ivor	3	1
Penydarren	5	2
Cytharfa	6	1
Hirwain	4	0
Duffryn and Furnace Ycha	8	0
Ynysfach	4	0
Aberdare	6	0
Aberammon	2	1
Gadlys	3	0
70 Furnaces	60	10

SOUTH WALES. (*Central Anticlinal District.*)

Principal Works:—	Blast Furnaces. In.	Blast Furnaces. Out.
Cwm Avon	4	2
Oakwood	2	0
Garth	0	3
Maesteg	0	3
Llynvi	4	0
Neath Abbey	0	2
20 Furnaces	10	10

SOUTH WALES. (*Western or Anthracite District.*)

Principal Works:—	Blast Furnaces. In.	Blast Furnaces. Out.
Venalt	0	2
Ystalyfera	5	6
Yniscedwin	3	4
Banwen	0	2
Onlluyn or Brin	2	0
Cwm Ammon	2	0
Trim Saren	0	3
Gwendrarth	0	3
Branere	0	2
34 Furnaces	12	22

South Wales. (*Southern Outcrop.*)

Principal Works:—	Blast Furnaces.	
	In.	Out.
Pentyrch	2	0
Toudu	1	1
Cefn Cusc	1	2
Cefn Cribbur	0	1
Dinas	3	0
11 Furnaces	7	4

The iron ore principally used at the Pentyrch works is hæmatite, from the carboniferous limestone on the south of the South Welsh coal-field. The annual production of iron on the south outcrop is about 25,000 tons.

North Wales.

Principal Works:—	Blast Furnaces.	
	In.	Out.
Rhuabon	2	1
Brymbo	1	1
5 Furnaces	3	2

Shropshire.

Principal Works:—	Blast Furnaces.	
	In.	Out.
Madeley Wood	3	0
Madeley Court	2	1
The Castle	1	1
Light Moor	2	0
Horse-hay	2	1
Lawley	1	0
Hinkshay	0	2
Stirchley	4	0
Dark Lane	0	2
New Lodge	1	1
Donnington	3	0
Sneds Hill	2	0
Langley	1	1
Ketley	1	1
33 Furnaces	23	10

South Staffordshire.

	Blast Furnaces.	
	In.	Out.
148 Furnaces	105	43

North Staffordshire.

Principal Works:—	Blast Furnaces.	
	In.	Out.
Silverdale	1	4
Apedale	2	2
Kidsgrove	3	0
Goldendale	2	1
Etruria	3	0
Longton	2	1
21 Furnaces	13	8

Yorkshire. (*Northern District.*)

	Blast Furnaces.	
	In.	Out.
Bowling	3	2
Low Moor	1	2
New Begin	2	0
Shelfe	0	1
Bierley	3	1
Farnley	1	0
16 Furnaces	10	6

Annual production of iron about 25,000 tons. The quality of iron made is very superior. The Low Moor and Bowling marks are especially celebrated. The beds of coal in this district are exceedingly thin. The Better Bed coal is the only one used for iron making purposes. The White Bed and Black Bed mines of this district probably correspond with the Thorncliffe White mine and the Clay Wood mine of the southern division of this field.

Yorkshire. (*Southern District.*)

Principal Works:—	Blast Furnaces.	
	In.	Out.
Worsbro' Dale	0	1
Elsecar	0	3
Milton	1	1
Thorncliffe	1	1
Chapeltown	1	1
Holmes	1	1
Parkgate	1	0
13 Furnaces	5	8

Annual production of iron about 20,000 tons, Thickness of measures from the Hobbimer to Mirtomley beds of coal about 430 yards. The entire thickness of the coal series is however much more. The measures thin out rapidly towards the north.

Derbyshire.

Principal Works:—	Blast Furnaces.	
	In.	Out.
Unston	1	0
Remshaw	1	1
Staveley	2	2
Duckmanton	0	1
Birmington Moor	1	0
Newbold	1	0
Wingerworth	1	1
Clay Cross	1	1
Morley Park	2	0
Alfreton	2	1
Butterley	2	1
Codnor Park	2	0
West Hallam	1	1
Stanton	2	1
29 Furnaces	19	10

Annual production of iron about 60,000 tons; average thickness of coal measures, from magnesian limestone to Kilburne or lowest worked coal, 600 yards. Many of the beds of ironstone lie in such a thickness of measure as only to be workable to advantage by open work or bell pits. Where these means of working can be adopted the produce per acre is oftentimes very large; in the Honeycroft Rake it is 6,000 tons per acre; in the black shale 8,000 tons.

Northumberland, Cumberland, and Durham.

Principal Works:—	Blast Furnaces.	
	In.	Out.
Walker	2	0
Tyne	2	0
Wylam	1	0
Hareshaw	0	3
Redesdale	0	3[*]
Birtley	1	2
Witton Park	3	1
Taw Law	2	3
Consett and Crookhead	7	7
Stanhope	1	0
38 Furnaces	19	19

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Annual production of iron about 90,000 tons. The iron works of this district are gradually increasing in importance, the cost of fuel being so low as to permit ores to be brought from many different localities. The bands of Scotland and of Haydon Bridge, the brown hæmatites and white carbonates of Alston and Weardale, and the argillaceous ironstones of the lias of Whitby and Middlesborough, are all used for the supply of the iron works of this district.

The brown hæmatites deserve especial attention. They are found associated in very large masses with the lead veins of this district, and occasionally they occur as distinct and regular beds. They contain from 20 to 40 per cent. of iron. Sometimes they exist as "riders" to the vein, sometimes they form its entire mass, and in this case they occasionally attain a thickness of 20, 30, and even 50 yards. Their employment for iron making purposes is only recent, but the supply of ore which they can furnish is almost unlimited, and when some better means of separating the zinc and lead associated with them shall have been discovered, they will doubtless be found to be of great importance Remarkable changes sometimes occur in the character of the metalliferous veins of this district; the same vein which at one point bears principally lead-ore changing to a calamine vein, and then again to brown hæmatites.

Lancashire and West Cumberland.

Principal Works:—	Blast Furnaces. In.	Out.
Cleator Iron Company	3	0
3 Furnaces.		

The production of iron in this district is very limited, being confined to the Cleator works and one or two small charcoal works in the Ulverstone district. The quality of the latter, charcoal being used for fuel, is very superior, and the produce commands the highest prices, as it combines with the fluidity of cast-iron a certain malleability, especially after careful annealing. The iron of the Cleator works is smelted with coal, and though in consequence not equal to the other, is yet superior in quality. The ore both of the Whitehaven and the Ulverstone and Furness districts is raised most extensively for shipment to the iron works of Yorkshire, Staffordshire, and North and South Wales. In quality these ores may be considered as the finest in this kingdom, and the supplies which these districts are calculated to produce are very great. The large percentage of iron which they contain, from 60 to 65 per cent., and their superior quality, also enable them to bear the cost of transport, and they are becoming every day of greater importance. They are found both as beds traversing the beds of mountain limestone formation transversely to the lines of stratification, and also as beds more or less regular. The former is the general character of the Ulverstone and Furness ores, no clearly defined bed being as yet known in that district, whilst at Whitehaven there are two, if not more, beds of irregular thickness, but with clearly defined floors and roofs, and oftentimes subdivided by regular partings. These beds attain a considerable thickness, occasionally 20 or 30 feet. The area over which they extend is not as yet well known; but they have been worked extensively for many years, and the workings upon them are rapidly increasing. They lie beneath and close to the coal measures, which both furnishes the necessary fuel, and also important beds of argillaceous ironstones for admixture.

Forest of Dean.

Principal Works:—	Blast Furnaces. In.	Out.
Cinderford	2	0
Forest of Dean Company	3	0
5 Furnaces	5	0

Annual production of iron about 30,000 tons. The ores of the Forest of Dean are carboniferous, or mountain limestone ores lying beneath the coal measures, which are not here productive in argillaceous ironstones, as in other principal coal fields of the kingdom. Besides the limestone ore there is a bed in the millstone grit measures; but which is only worked very locally. The limestone ore occupies a regular position in the limestone measures, although in itself exceedingly irregular, assuming rather the character of a series of chambers than a regular bed. These chambers are sometimes of great extent and contain many thousand tons of ore, which is generally raised at an exceedingly low cost, no timbering or other supports for the roof being required. The supply of ore producible in the Forest of Dean is almost unlimited. The iron made from it is of a red short nature, and especially celebrated for the manufacture of tin plates. Its superior quality always commands a high price. This ore is raised extensively for shipment to the iron works of South Wales. It was worked at a very ancient date, either by the Romans or the Britons, as is evident from the remains of old workings along the outcrop of the ore bed. This ore averages from 30 to 40 per cent.

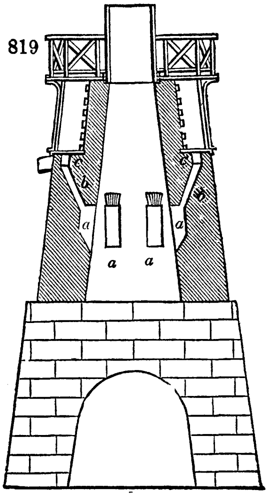
For certain new processes for making malleable iron, Mr. W. N. Clay has obtained two successive patents. Under the first, of December, 1837, he mixed bruised hæmatite with one-fifth of its weight of clean carbonaceous matter in coarse powder, and subjected the mixture in a ⩀ shaped retort to a bright red heat for twelve or more hours, till the ore be reduced to the metallic state, as is easily ascertained by applying a file to one of the fragments. When discharged, the metal is to be transferred into a balling or puddling furnace, along with about five per cent. of ground coke or anthracite, and worked therein in the usual way. He also proposes to use a conical kiln, like that for burning lime, instead of the retorts.

In his second patent, dated March, 1840, Mr. Clay prescribes above 28 per cent. (from 30 to 40) of carbonaceous matter to be mixed with the ground-iron ore, containing at least 45 per cent. of metal, which mixture is to be directly treated in a puddling furnace. He also proposes to use a mixture of pig or scrap iron and ore, in equal quantities.

The application of the waste gases (carbonic oxide chiefly) of the blast furnace to the purpose of heating the puddling or balling furnace, was made the subject of a patent in June, 1841, by a foreigner not named. The process had been previously practised in Germany, and was fully described in the *Annales des Mines* some years ago.

In *fig.* 819. the manner of conveying the waste carbonic oxide from a blast furnace is shown. *a*, *a*, *a*, are openings leading into the vertical channels or passages *b*, and from thence into the chamber *c*. There is a top to this chamber, with openings corresponding to the passages *b*. These openings are closed with cast-iron plates that can be taken off for the purpose of clearing out the passages *b*, and the chamber *c*. From the chamber *c*, the gas may be conducted in any direction, and to a distance of several hundred feet.

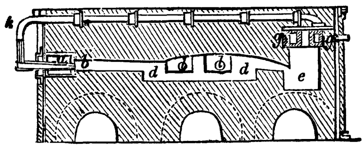
819



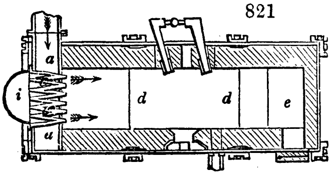
In some localities, and in cases where it is required to take the gas from a blast furnace in operation, a metal cylinder, of a smaller diameter than the top of the furnace, and of a depth equal to its diameter, is suspended vertically within the top of the blast furnace the whole of its length. The space between the cylinder and the furnace at the top or mouth is to be hermetically sealed, and the furnace is to be charged through the cylinder which must be kept full of minerals and combustibles. Thus the space between the cylinder and the interior of the furnace remains vacant, but the gas may be conducted out of that part laterally, if required. The gases led off from the blast furnace may, if need be, pass through heated pipes, as for the hot blast

Figs. 820. and 821. represent a refining furnace for iron, with the necessary apparatus for working it with the gases, without the use of other fuel; *fig.* 820. being a vertical section, and *fig.* 821. a sectional plan view.

820



821



The gas from the blast furnace is brought into the chamber *a a*, and, passing through an opening *b b*, it enters the furnace. *c c* are a series of blow pipes, through which the heated air is forced into the furnace. In the space between the part marked *b* and the tubes *c*, the gas becomes mixed with the heated atmospherical air.

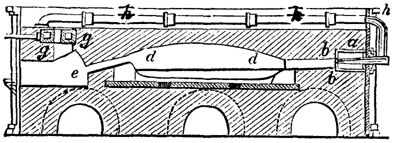
This combustible gas from the blast furnace, mixed with the heated air, produces an intense heat in the furnace, adequate to the refining of iron. The warm air for burning the gas is usually obtained from the blowing machine and hot blast pipes.

For giving a still greater heat, the air may be carried through the tube *f*, into the iron chambers *g g*, or a system of pipes, whence it is led through the tube *h* into the semi-circular chamber *i*, and then through the small pipes *c*, *c*, *c*, into the furnace.

The metal to be refined is placed in the space *d d*, in a liquid state, if the arrangement of the furnaces will admit of its being so taken from the blast furnace; if not, it may be nearly melted by the waste heat in the chamber *e e*. In order to decarbonize the metal, a quantity of warm air, from the pipe *h*, is conducted through the pipe *k*, which is divided into two nozzles or *tuyères l l*, and blown upon the fluid metal in the space *d d*. After having been thus exposed for an hour or two, it is run off through the opening *m*, and will be found in a refined state.

Figs. 823, 824, show the application to a puddling furnace. The openings *n n* admit a stream of cold water to flow through the cast-iron piece *o o*, to preserve it from injury by the fire.

824



823

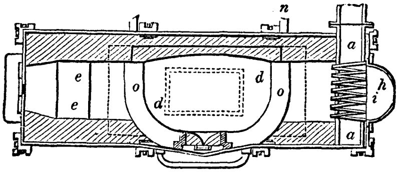
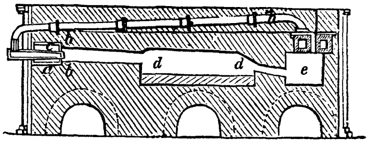


Fig. 824 is a welding furnace; the interior dimensions and the casing of the hearth being different, as well as the fire bridge, from those of the puddling furnace. The pipes for conducting the gases are made of cast-iron, and must have at least a sectional area of one foot for every furnace that is to be heated.

Figs. 825, 826, 827, 828, 829. show the application of this invention to the generation of steam. A chimney is here employed only at the commencement of the operation. The air is forced into the furnace by any sort of blowing machine, or in any other convenient way. The fuel is introduced into the fireplace, upon the grate *n n*, through the door *a*, which can be closed. The fireplace must contain as much fuel as will last for several hours. When the fire is first lighted, the combustion takes place in the ordinary way, on opening the door *d*, and the slide-valve *b*, and carrying through them a current of air by the chimney draught. This is continued till the steam-engine furnace, or any working (power) engine is in operation, after which a blowing apparatus is employed to force the air through the tube *c*, as shown in *fig.* 826. The openings *d*

822



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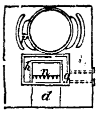
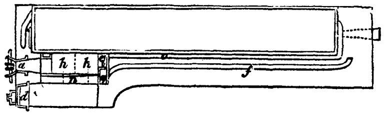


825



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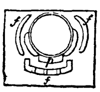
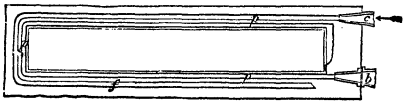
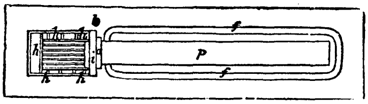


826



827

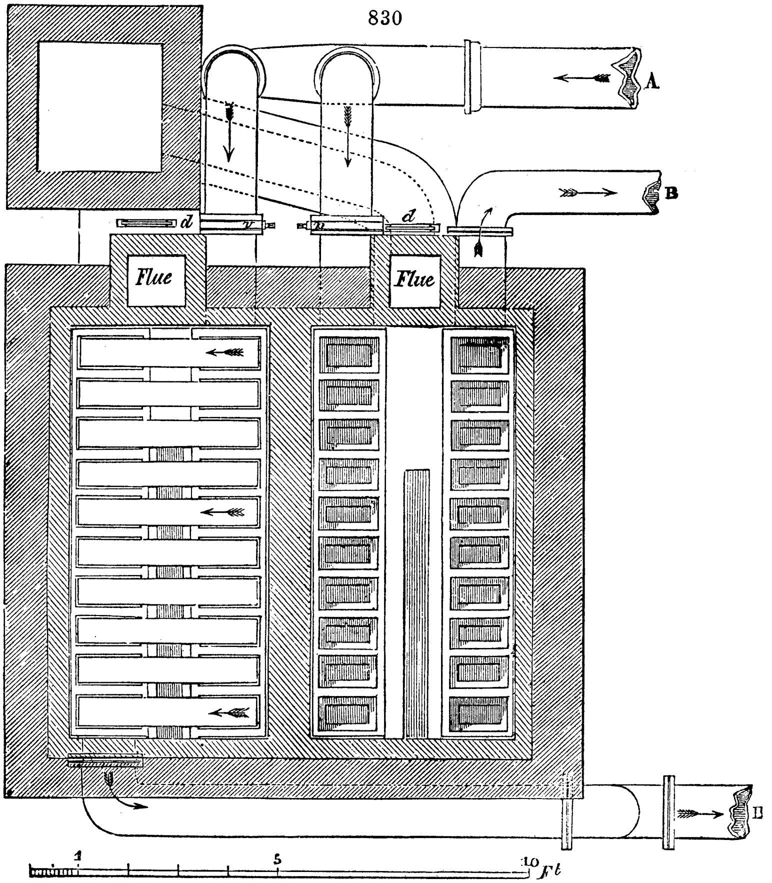


and b are then closed; the air forced in now passes through the flues f, f, f, placed round and beneath the boiler. The air, on arriving at the point g, is divided, one portion passes through the opening h, regulated by a valve, into the open space beneath the grate n n, to assist in the slow combustion of the fuel. The other part of the air passes through g, into h h, round the fire-place, in order to heat the air to an intense degree. After the second portion of the air has passed into the chamber h h, it enters another i i, thence through a series of blowpipes, or through o, into p p, beneath the boiler. The burnt air goes off through p p, into a small chimney, through the opening b b, which is regulated by a valve.

IRON. *Hot Blast.* To the account of this interesting innovation in the smelting of iron ores, given in the dictionary, I have now the pleasure of representing in accurate plans, the complete system mounted at the Codner Park Works belonging to William Jessop, Esq. For the drawings, from which the woodcuts are faithfully copied, I am indebted to Mr. Joseph Glynn, F.R.S., the distinguished engineer of the Butterly Iron Works.

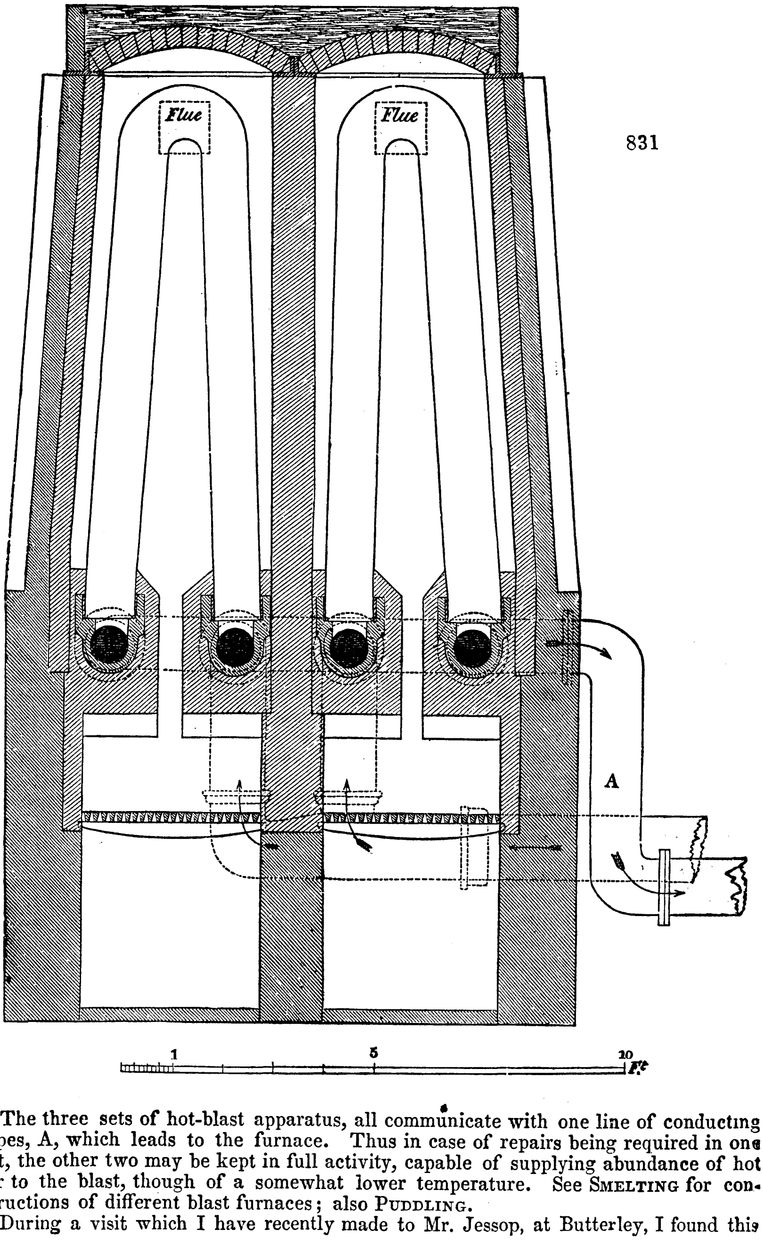
Figs. 830, 831, 832, exhibit the apparatus of the hot blast in every requisite detail. The smelting furnaces have now generally three tuvères, and three sets of air heating furnaces. The figures show two sets built together; the third set being detached on account of peculiar local circumstances. The air enters the horizontal pipe A, in the ground plan, *fig.* 830, on one side of the arched or syphon pipes, shown in upright section in *fig.* 831, and passes through these pipes to the horizontal pipe, B, on the other side; whence it proceeds to the blast furnace. These syphon pipes are flattened laterally, their section being a parallelogram, to give more heating surface, and also more depth of pipe (in the vertical plane), so as to make it stronger, and less liable to

830



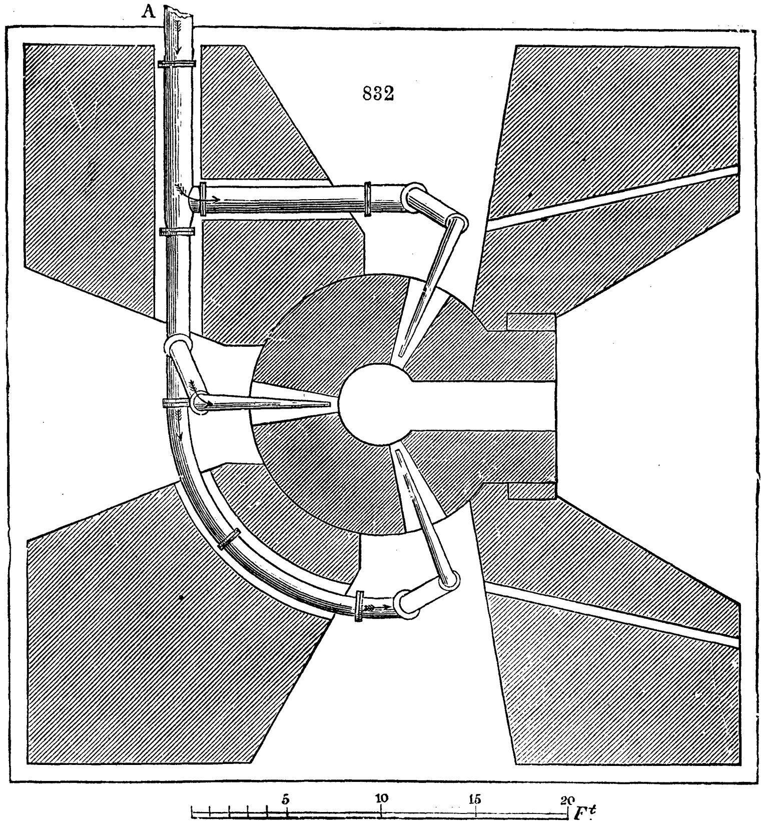
bend by its own weight when softened by the red heat. This system of arched pipe apparatus is set in a kind of oven, from which the flue is taken out at the top of it; but it thence again descends, before it reaches the chimney, entering it nearly at the level of the fire grate (as with coal gas retorts). By this contrivance, the pipes are kept in a bath of ignited air, and not exposed to the corroding influence of a current of flame. The places and directions of these oven flues are plainly marked in the drawing.

Fig. 832 is a plan of the blast furnace, drawn to a smaller scale than that of the preceding figures.



The three sets of hot-blast apparatus, all communicate with one line of conducting pipes, A, which leads to the furnace. Thus in case of repairs being required in one set, the other two may be kept in full activity, capable of supplying abundance of hot air to the blast, though of a somewhat lower temperature. See Smelting for constructions of different blast furnaces; also Puddling.

During a visit which I have recently made to Mr. Jessop, at Butterley, I found this



eminent and very ingenious iron-master had made several improvements upon his hot-blast arrangements, whereby he prevented the alteration of form to which the arched pipes were subject at a high temperature, as also that he was about to employ five tuyères instead of three. For a drawing and explanation of his furnace-feeding apparatus, see SMELTING.

IRON CAST, *improved by combination with wrought iron.* This improvement, invented and patented by Mr. Morries Stirling, has been reported upon by the Government Commissioners on the application of iron to railway purposes. It is applicable to both cast and wrought iron. A mixture of the two in certain proportions has the effect of giving a fibrous nature to the cast metal, and thereby greatly increasing its strength and tenacity. For all kinds of beams, girders, and other castings where strength is required, its use is found very advantageous and economical. Beams cast of such toughened iron may be made of less dimensions to support the same load; and they have the advantage of deflecting to a greater extent, and are therefore not so liable to sudden failure. At page 101. of the Commissioners' Report, an abstract is given of a series of trials, from which it will be seen that Mr. Stirling's alloy is nearly 50 per cent. superior to 16 other sorts of iron experimented upon. Various other experiments have been made by Mr. Owen for the Admiralty, and by Messrs. Rennie and others, all with the same results, showing the increase of strength in the patent iron. Common Scotch pig iron thus toughened can be had now (1851) for about 2*l.* 10*s.* per ton; and it is at least 50 per cent. stronger than the best Blaenavon iron, which costs 3*l.* 3*s.* per ton.

The improvements in the manufacture of *wrought* iron are, first, the admixture of a certain alloy in the puddling furnace, by which all malleable iron is rendered much more fibrous and tougher than common wrought iron, so much so that common or merchant bar becomes equal to best bar, thus saving one process to the manufacturer. Also very ordinary iron, which can scarcely be used at all, is made equal to the best. The following abstracts of experiments are given in the Report of Commissioners (p 417.)

	Breaking Strain in Tons per Square Inch.
Average of Mr. Jesse Hartley's experiments at Liverpool on many sorts of malleable iron	23·23
Average of S. C. Crown Iron from numerous trials at Woolwich Dockyard	24·47
Average of best Dundyvan bar	24·33
Average of Mr. Sterling's best quality	27·81
Do. another quality	27·70

The cost of the process is only a few shillings per ton. When Mr. Stirling's toughened pig is used in the puddling furnace instead of common pig, and the alloy added, an iron is produced of a very superior quality, of a very fibrous nature, and much finer in the fibre than the iron mentioned above; this will be found very advantageous in the manufacture of thin plates and sheets.

Second, the admixture of a different alloy in the puddling furnace, whereby a quantity of iron is produced quite opposite in its character to the last; instead of being fibrous, it becomes hard and crystalline, approaching to the nature of steel. The average strength of common round bars, 1 inch diameter, is about 3 inches per foot; whereas the average of Mr. Stirling's hardened iron is from one-eighth to three-eighths of an inch per foot. This shows the great stiffness obtained by this method. The crystalline nature of this description of iron causes it to resist compression, lamination, and abrasion. Thus for the top portions of wrought iron girders, it is precisely what is required to resist the compression force, the fibrous iron being used for the bottom portion, to resist the tension. For rails and tyres for wheels this sort of iron is peculiarly adapted; the top of the rails and the outside of the tyres being made with it, will resist the wear and tear and lamination so universally complained of; and rails made of the patent iron are found to answer remarkably well. They have been used on the East Lancashire, Caledonian, Edinburgh and Glasgow, and other railways, with great success; the extra cost of rails made of this iron being only from 7*s.* 6*d.* to 10*s.* per ton.

The first of these improvements in the manufacture of metallic sheets is the use of polished rolls to such sheets as are either intended for being coated with other metals, or after such sheets have been so coated; and this improvement is more particularly applicable to iron plate either coated or to be coated with tin, zinc, or other of the more fusible metals. After the plates or sheets of iron have been cleaned by pickling or otherwise in the usual way, they are to be passed between polished rollers, using sufficient pressure to smooth the surface without injuring the quality by producing brittleness; and as iron is of such different qualities as regards its ductility, both when hot and cold (according to the district from whence the ore is produced, and peculiarities of make,) no absolute rule respecting the amount of pressure can be given, but a little practice will enable a workman to judge, and care is to be taken that the rolls are clean. The plates so polished are then to be dipped in the usual manner into the metal or alloy intended for the coating. After the plates or sheets have been coated with any metal or alloy, they are, where a high degree of smoothness is desired, again passed between polished rolls, the degree of pressure being carefully regulated so as to avoid producing brittleness. It is not essential that the sheets of metal should be passed between the smooth rolls before coating, but it is preferred that such should be the case.

Iron Cast, Enamelled. The Great Exhibition contained the following examples.

Model of an enamelled tank or cistern composed of cast iron plates, screwed together with gutta percha joint.

Model of enamelled water or gas pipes and watercloset pan, with trap pipe; dry trough, poultry trough, and spittoon.

The application of enamel for the protection of water cistern pipes, &c. from oxidation and for the lining of cooking utensils is of comparatively recent date. The various materials of which the coating is composed (silex being the principal) are reduced to a fluid state; the article to be coated is dipped in the mass; a portion of the fluid adheres; it is then subjected to the heat of a muffle, and the whole becomes vitrified or reduced into a glossy covering, affording an excellent defence against oxidation, and a substitute for the protection afforded by tinning.

Iron, Zinking of. See Zinking.

IRON ORES (*Analysis of, by Bichromate of Potash*). A convenient quantity of the specimen is reduced to coarse powder, and one-half at least of this still further pulverized, until it is no longer gritty between the fingers. The test solution of bichromate of potash is next prepared. 44·4 gr. of the salt in fine powder are weighed out, and put into an alkalimeter (graduated into 100 divisions), and tepid distilled water afterwards poured in until the instrument is filled to 0. The palm of the hand is then securely placed on the top, and the contents agitated by repeatedly inverting the in-

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strument until the salt is dissolved, and the solution rendered of uniform density throughout. It is obvious that each division of the solution thus prepared contains 0·444 gr. of bichromate, which corresponds to ½ a grain of metallic iron. The bichromate of potash used in this process must of course be purchased pure, or made so by repeated crystallization, and it should be thoroughly dried by being heated to incipient infusion.

100 grains of the pulverized ironstone are now introduced into a Florence flask, with 1½ oz. by measure of strong hydrochloric acid, and ½ an ounce of distilled water. Heat is cautiously applied, and the mixture occasionally agitated, until the effervescence caused by the escape of the carbonic acid ceases; the heat is then increased and the mixture made to boil, and kept at moderate ebullition for ten minutes or a quarter of an hour. During these operations it will be advisable to incline the flask, in order to avoid the projection and consequent loss of any portion of the liquid by spirting. About 6 oz. of water are next added, and mixed with the contents of the flask, and the whole rapidly transferred to an evaporating basin. The flask is rinsed several times with water to remove all adhering solution.

Several small portions of a weak solution of pure red prussiate of potash (containing 1 part of the salt to 40 of water) are now dropped upon a white porcelain slab, which is conveniently placed for testing the solution in the basin during the next operation.

The prepared solution of bichromate of potash in the alkalimeter is then added very cautiously to the solution of iron, which must be repeatedly stirred, and as soon as it assumes a dark greenish shade, it should be occasionally tested with the red prussiate of potash. This may be easily done by taking out a small quantity on the end of a glass rod, and mixing it with a drop of the solution on the porcelain slab. When it is noticed that the last drop communicates a distinct red tinge, the operation is terminated. The alkalimeter is allowed to drain for a few minutes, and the number of divisions of the test liquor consumed read off. This number multiplied by 2 gives the amount of iron per cent. in the specimen of ironstone, assuming that, as directed, 100 grs. have been used for the experiment. The necessary calculation for ascertaining the corresponding quantity of protoxide is obvious.

When black-band ironstone is the subject of analysis, or when the ore affords indications by its appearance, or during the treatment with hydrochloric acid, that it contains an appreciable quantity of carbonaceous matter, then the hydrochloric acid solution must be filtered before being transferred to the basin, and the filter, with the insoluble ingredients, must be washed in the usual way with warm distilled water, slightly acidulated with hydrochloric acid, until the filtrate ceases to give a blue colour with red prussiate of potash. In those cases, also, where the presence of iron pyrites in the ironstone is suspected, it will be necessary to remove the insoluble matter by filtering before using the bichromate solution; but with ironstones in which the insoluble ingredients are merely clay and silica, filtration is not essential.

Now it is evident that the foregoing process, so far as I have described it, serves for the determination of that portion of iron only which exists in the ore in the state of protoxide. But many specimens of the common ironstone of this country contain appreciable quantities of peroxide of iron, which, being unacted upon by the bichromate of potash, would escape estimation by the present method. By an additional and easy operation, however, the amount of metallic iron in this ingredient may be likewise determined. It is only necessary to reduce it to the minimum state of oxidation, and then to add the bichromate, as previously directed.

The best and most convenient agent for effecting the reduction of the persalts of iron, is sulphite of soda. The only precaution to be observed is to use it in sufficient quantity, and at the same time to take care that the iron solution contains excess of acid. When the reduction is complete, a few minutes' ebullition suffices to decompose the excess of sulphite of soda, and effectually to expel every trace of sulphurous acid.

In order to test the exactness of this mode of estimating the iron in the peroxide, I made several experiments with peroxide prepared from known quantities of pure iron wire. The peroxide was thoroughly washed, dissolved in hydrochloric acid, reduced with sulphite of soda, and after complete expulsion of the excess of sulphurous acid, the solution was diluted with water and treated with bichromate of potash. I select three of the experiments:—

Exp. I.	10 grs.	of iron	consumed	8·87	of bichromate.
Exp. II.	18	do.	do.	15·94	do.
Exp. III.	25	do.	do.	22·15	do.

The mean of all my experiments on this point gives the ratio of 100 of iron to 88·6 of bichromate, which is in close accordance with the former results.

Whenever, therefore, the ore of iron contains peroxide, it will be necessary to add sulphite of soda to the hydrochloric acid solution before the addition of the test liquor from the alkalimeter. The sulphite should be dissolved in distilled water, and added to the solution of iron in small successive portions, until a drop of the liquor gives merely a rose pink colour with sulpho-cyanide of potassium, which indicates that the reduction of the persalt of iron is sufficiently perfect. The liquid is now heated till the odour of sulphurous acid is no longer perceptible These operations should be performed while the solution is in the flask, and before it is filtered or transferred to the basin.

I will here mention, for the guidance of those who may not be fully aware of the reactions of the oxides of iron, that the existence of an appreciable quantity of peroxide in the ironstone may be readily discovered by dissolving (as directed in the process) 30 or 40 grs. of the ore in hydrochloric acid, diluting with about 8 oz. of water, filtering and testing a portion of the solution with sulpho-cyanide of potassium. If a decided dark blood-red colour is produced, the quantity of peroxide in the stone must be determined; but if the colour is only light red or rose pink, the proportion is exceedingly small, and for practical purposes not worth estimating. Of course, when the specimen of ironstone has an ochrey or a reddish appearance on the surface or in the fracture, the presence of a large proportion of peroxide is indicated, and its exact quantity must be determined.

In conclusion, I must not omit to notice one or two circumstances which appear at first to militate against the accuracy of this process. It may be questioned whether solutions of the protosalts of iron do not absorb oxygen so rapidly from the air as to influence the results obtained by this method. Marguerite has shown, and my own observations completely confirm his statement, that protosalts of iron, in an acid solution, become peroxydized very slowly; and, in a particular experiment, I found that contact with the air during several hours caused no diminution in the quantity of bichromate of potash required. As the process may be completed in a few minutes, it is certain that no inaccuracy can arise from this cause.

It is also important to inquire whether the chromic acid in the chromates of potash may not be partially deoxydized by hydrochloric acid alone without the presence of a protosalt of iron. Such a reaction would obviously give rise to a serious error. It is well known that concentrated hydrochloric acid rapidly decomposes the chromic acid of the chromates when aided by the application of heat. But I have satisfied myself, by numerous experiments, that this acid exerts very little appreciable action upon dilute solutions of the chromates of potash, either cold or warm, and that the action is only partial even after continued ebullition; so that the present method is free from inaccuracy on this account.—*Dr. Penney.*

Bronzing of polished iron.—The barrels of fowling-pieces and rifles are occasionally bronzed and varnished, to relieve the eye of the sportsman from the glare of a polished metal, and to protect the surface from rusting. The liquid used for browning the barrels is made by mixing nitric acid of specific gravity 1.2, with its own weight of spirit of nitric ether, of alcohol, and tincture of muriate of iron; and adding to that mixture a quantity of sulphate of copper equal in weight to the nitric acid and ethereous spirit taken together. The sulphate must be dissolved in water before being added; and the whole being diluted with about 10 times its weight of water, is to be bottled up for use. This liquid must be applied by friction with a rag to the clear barrel, which must then be rubbed with a hard brush; processes to be alternated two or three times. The barrel should be afterwards dipped in boiling water, rendered feebly alkaline with carbonate of potash or soda, well dried, burnished, and heated slightly for receiving several coats of tin-smith's lacquer, consisting of a solution of shellac in alcohol, coloured with dragon's blood.

ISINGLASS, or Fish glue, called in Latin *ichthyocolla*, is a whitish, dry, tough, semi transparent substance, twisted into different shapes, often in the form of a lyre, and consisting of membranes rolled together. Good isinglass is unchangeable in the air, has a leathery aspect, and a mawkish taste, nearly insipid; when steeped in cold water it swells, softens, and separates in membranous laminæ. At the boiling heat it dissolves in water, and the solution, on cooling, forms a white jelly, which is semi-transparent, soluble in weak acids, but is precipitated from them by alkalis. It is gelatine nearly pure; and if not brittle, like other glue, this depends on its fibrous and elastic texture. The whitest and finest is preferred in commerce. Isinglass is prepared from the air-bladders of sturgeons, and especially the great sturgeon, the *accipenser huso;* which is fished on the shores of the Caspian Sea, and in the rivers flowing into it, for the sake chiefly of its swim bladder.

The preparations of isinglass in this part of Russia, and particularly at Astracan, consists in steeping these bladders in water, removing carefully their external coat, and the blood which often covers them, putting them into a hempen bag, squeezing them, softening them between the hands, and twisting them into small cylinders, which are afterwards bent into the shape of a lyre. They are ready for the market immediately after being dried in the sun, and whitened with the fumes of burning sulphur.

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